

# INDIA'S MINERAL WEALTH

*A Guide to the Occurrences and Economics  
of the Useful Minerals of the  
Indian Empire*

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## INTRODUCTION

FIFTY years ago little systematic mining had been done on such Indian ore deposits as were known at that time, and without this, it is difficult to form any accurate judgement of their modes of occurrence, or of their potentialities. The author of the pioneer work on Indian economic geology which was published in 1881, wrote as follows: 'Hitherto mining for metallic ores by British companies has not been successful in this country, though coal and salt mining and the quarrying of building materials have been carried on by the Government or by private companies, with in many cases very great profit. It would seem, however, that, as regards the metals there is a new era about to commence, and that the capabilities of India, not only as a gold-producing country, but also in reference to other metals, will in the course of the next few years be for the first time fairly tested.' Valentine Ball read the signs of his times correctly, for the developments of the next decade or two fully justified the truth of his prediction. Mineral deposits of many kinds were discovered and opened up; the platitude that they were as a rule too lean to support large-scale treatment died a natural death, and although for a time exploitation resulted mainly in the export of raw materials to other countries, the advantages to be gained by dealing with them on the spot have been slowly realized, and India is now advancing to her proper position amongst the metallurgical nations of the world.

By 1899 the growth of prospecting necessitated the issue by the Government in that year of rules to govern the grant of prospecting licences and mining leases, and the number of concessions taken up by private individuals and companies over lands in which the mineral rights have been retained by the State, rapidly increased from an average of 370 per annum for the first decade of the century to 706, the corresponding figure for the ten years ending 1930.

To register the progress of the mineral industry, a *Review of the Mineral Production of India* was issued annually by the Reporter on Economic Products to the Government of India, for the four years 1894-97, but in 1898 it was decided to publish reviews of progress



at wider intervals, covering periods long enough to permit of the determination of any secular variations. The first of these reviews, dealing with the six years 1898-1903, appeared in the *Records of the Geological Survey of India* in 1905, and since then quinquennial reviews have been forthcoming regularly. In addition to these, a brief annual statement of the quantity and value of all the minerals raised, for which returns are available, has appeared each year in the *Records* since 1906.

Apart from the papers on mineral deposits scattered through the sixty-eight volumes of the *Records of the Geological Survey of India*, and the monographs devoted to subjects such as coal, petroleum, mica, gold, manganese, etc., which have been published from time to time as memoirs of the same department, there exists a great and growing literature on Indian geology, a list of which was assembled and made accessible through the labours of T. H. D. La Touche. His *Bibliography of Indian Geology and Physical Geography*, published in 1917, contains references to the papers of 1,989 authors. In Part II, issued in 1918, a guide to the literature on the minerals of economic importance is provided, together with a brief account of the information given by each observer. An index of localities in 1921 was followed by a subject index in 1923. The bibliography is kept up-to-date by the publication of a list of the most recent papers, as an appendix to the *Annual Reports of the Geological Survey of India*.

Sir Thomas Holland's *Sketch of the Mineral Resources of India* appeared in 1908, and the first edition of the present book, published in 1923, was written on much the same lines and aimed at presenting the main facts then known about each mineral in as condensed and popular a form as possible. In the first edition it was pointed out that an account written in 1908 was more or less obsolete then, and the last decade has again registered much progress and witnessed many further developments. Sir Thomas Holland dealt with 54 distinct mineral products, our earlier edition described 77, a number now raised to 110. About 1908 the total annual value of minerals raised, for which production returns of a fairly reliable character are available, averaged £7 million; about 1928, the corresponding figure was nearly £24 million and today, in spite of the effects of an unprecedented world depression, is in the neighbourhood of £18 million. Since that time several new coalfields have been opened; fresh oilfields drilled and the unknown depths of existing

ones explored; the enormous iron ore fields of Bihar and Orissa have been proved and a great iron and steel industry with its attendant satellites has been established. Metallurgical centres have also arisen at Maubhandar in Bihar, where the copper ores from the Singhbhum lodes are treated and refined copper and yellow metal products are manufactured in increasing quantities, and at Nan Tu in the Federated Shan States, where the ores from the Bawdwin mine are made to yield their lead, silver, copper, antimony and nickel contents, and zinc concentrates are also prepared. The wolfram deposits of Lower Burma are now known to be the most important in the British Empire, while the associated tin ore is recovered both by underground mining and by modern dredging methods. The valuable beach sands of Travancore, the largest and the richest in monazite in the world, with the diminution in the demand for that particular mineral as a result of the replacement of gas by electricity for lighting purposes, are now also treated for their ilmenite and zircon contents. With the growth of the iron and steel industry the demand for refractory materials has resulted in the creation of works specializing in the production of such goods, while Indian cement works now satisfy most of the country's needs. India still heads the list of the world's mica producers and her manganese ore deposits continue to give her the same position from time to time. In some directions, on the other hand, progress has been disappointingly slow, and vast quantities of materials made in other lands from mineral products continue to be imported. Apart from such controversial questions as the possibilities of the successful inauguration of aluminium, zinc and tin extraction, or the production of ferro-alloys and other products in the electric furnace, the manufacture of sulphuric acid and heavy chemicals generally, of artificial fertilizers, of hardware and light iron and steel articles, of glass, earthenware and porcelain, of paints and colours and of many products used in building construction and now obtained from abroad, on a much larger scale than at present exists, from the raw materials which the country can provide in abundance, continue to demand and to merit attention. These are fundamental problems which must be solved if the progressive evolution of India's industrial life is to keep pace with its national advancement.

Indian mineral statistics are grouped officially into two classes, (1) those for which approximately trustworthy annual returns are available, and (2) those for which regular and complete particulars

are not forthcoming. In Table 1 the values of a series of minerals and mineral products belonging to the first class are tabulated over seven periods ranging from 1898 to the present time, and while some comparatively unimportant ones have disappeared from the list, the pronounced rise in the majority of cases is striking and the effects of the existing depression are evident in the latest figures given. Such statistics are for the most part of internal comparative value only, as an indication of the trade in the particular substance with which they deal. With reference to the absolute values of the mineral products of other countries, they are liable to mislead without further interpretation. For example, the value of coal represents an approximate pit's mouth figure, which bears little relation to the selling price in the open market; the value of petroleum previous to 1919 was greatly underestimated; the value of salt is exclusive of its duty, which is the main source of income derived by the Government from its manufacture; the export value of mica is not connected in any apparent way with the declared value of the production at the mines; or, again, the value of rubies and associated gems represents the output of a single European company, while the results of an active indigenous industry have never been tabulated. Further instances might be given but these suffice to show the necessity for a separate analysis of each case, particularly in attempts to visualize future tendencies.

In the pages which follow, each useful mineral which India produces is considered individually, the chief occurrences are briefly described, the history of its commercial exploitation is outlined, and with the exception of the commoner metals its uses are explained. Outputs and their values from the commencement of operations, or from the beginning of the present century, are presented, and comparisons made with imported articles when these are considered essential to a proper appreciation of the economic position; and finally, for the benefit of Indian students of economic geology on whom the task of searching for new mineral deposits in their own land will fall more and more in future, brief notes on the important questions of origins have been incorporated, for the author's twenty-seven years' work in connexion with these matters has taught him their value as a preparation for field work. The first edition of *India's Mineral Wealth* has been entirely rewritten and enlarged, primarily with the object of drawing attention to the commercial and industrial potentialities

**TABLE I**  
**AVERAGE ANNUAL VALUES OF CERTAIN INDIAN MINERALS AND THEIR PRODUCTS**  
**METALS AND ORES**

	1898-1903	1904-08	1909-13	1914-18	1919-23	1924-28	1929-32
	£	£	£	£	£	£	£
Antimonial Lead ...	...	...	...	...	...	20,532 <sup>3</sup>	18,215
Chromite ...	...	9,110	4,282	20,164	53,764	47,224	42,784
Copper Ore and Matte ...	...	...	...	12,418	29,053	294,801	437,597
Gold ...	1,904,719	2,266,307	2,241,844	2,258,653	2,094,323	1,668,067	1,593,302
Ilmenite ...	...	...	...	...	...	16,892	40,430
Iron Ore ...	13,584	13,769	29,519	34,819	114,956	351,971	362,031
Lead and Lead Ore ...	...	...	128,782	358,970	881,710	1,653,569	1,237,926
Manganese Ore <sup>1</sup> ...	79,443	631,760	822,876	1,052,403	1,995,341	2,018,835	909,560
Nickel Speiss ...	...	...	...	...	...	10,620 <sup>4</sup>	57,163
Silver ...	...	...	9,341	135,929	642,450	756,148	558,161
Tin and Tin Ore ...	6,875	10,992	30,100	73,376	214,500	352,846 <sup>5</sup>	345,943
Wolfram ...	...	...	76,481	461,698	135,845	36,192	91,372
Zinc Concentrates...	...	...	...	...	...	376,345	210,181

**FUELS**

Coal ...	1,225,677	2,139,249	2,969,305	4,419,174	9,252,649	8,305,764	6,193,893
Petroleum ...	185,810	592,887	928,072	1,073,604	7,036,298	6,268,229	4,222,109

**GEMS AND SEMI-PRECIOUS STONES**

Amber ...	362	648	182	280	874	1,267	163
Diamonds ...	...	2,799	872	1,216	7,262	2,691	5,714
Jadeite <sup>1</sup> ...	44,770	61,353	55,373	74,498	114,329	32,843	26,730
Ruby, Sapphire and Spinel ...	89,345	84,406	63,272	41,817	60,660	26,228	6,613

**OTHER MINERALS**

Graphite ...	11,981	12,879	16,363	641	265	...	...
Magnesite ...	519	689	2,403	7,568	16,334	21,559	5,904
Mica ...	80,120	170,126	230,747	373,370	633,331	737,930	476,315
Monazite...	...	...	35,825	45,334	29,294	3,060	2,244
Salt <sup>2</sup> ...	347,897	451,339	507,294	902,623	948,245	741,468	924,350
Saltpetre <sup>1</sup> ...	262,603	268,012	240,289	473,188	355,118	127,221	72,713
Zircon ...	...	...	...	...	...	4,542	6,893
Total £	4,253,705	6,716,325	8,393,222	11,822,743	24,616,601	23,876,844	17,848,306

<sup>1</sup> Export values.

<sup>2</sup> Prices without duty.

<sup>3</sup> Includes antimony ore.

<sup>4</sup> Production commenced 1927.

<sup>5</sup> Tin ore exclusively in and after this period.

which the mineral deposits possess and in the hope that capital and enterprise will be forthcoming for their further development, with all that it means for the lasting benefit of India and the Indian peoples.

In a conspectus of this kind information has to be drawn from many sources and in case of an unintentional omission of acknowledgment in the proper place, thanks are tendered here to all the past and present officers of the Geological Survey of India and others whose work has been made use of. I am particularly indebted to the Government of India for permission kindly granted to produce this book; to the writers of the *Annual* and *Quinquennial Reviews of Mineral Production in India*, Sir Thomas Holland, the late Sir Henry Hayden, Sir Edwin Pascoe and Dr L. L. Fermor; to Sir Thomas Holland again for his *Sketch of the Mineral Resources of India* and to Mr T. H. D. La Touche for his *Bibliography of Indian Geology*; to the Director of the Geological Survey of India for permission to use various graphs, maps and photographs; to the various firms mentioned later for their courtesy in supplying photographs, some of which were taken specially for this book, and to various authorities who have in some cases read and criticized my notes.

In an appendix a few references to papers are given in the hope that they may prove useful to the reader desirous of following the subject further than the limited space here permits. In this connexion attention is invited to my notes on Indian minerals published as *Bulletins of Indian Industries and Labour* in 1921 and 1922. These deal with the ores of manganese, lead, zinc, tin, chromium, tungsten, molybdenum, antimony, arsenic and bismuth; with bauxite, mica, asbestos, magnesite, monazite, corundum, garnet, barytes and the mineral colours. They were followed by others on sulphur and sulphuric acid and on glass-making materials by Dr C. S. Fox. Their chief object was to explain to the Indian producer the manner in which manufacturers generally obtain their supplies, the systems of buying and selling, the regulations of the mineral trade associations, the standard specifications and contract forms of metallurgical firms and dealers, the recognized market grades and the units of sale.

The appendix also contains statistical information relating to periods later than those considered in the text.

Finally, I alone accept responsibility for statements regarding the future development of any particular mineral industry, unless the opinions of others are quoted.

PART I

THE MINERAL FUELS

## CHAPTER I

### COAL, LIGNITE, PETROLEUM, OIL SHALE AND NATURAL GAS

#### COAL

COAL is India's most valuable mineral product and its winning one of her more important industries. Over 200,000 workers find employment in or about the coal mines in normal times and nearly 98 per cent of the production is consumed in the country. The railways are the largest users and take approximately one-third of the output. They are followed by the iron and steel industry, while the remainder supplies power for a host of other establishments, mills and factories of every description. After the United Kingdom India is the largest coal-producing unit of the British Empire and over the past few years her output has averaged, approximately, 23 million tons, as compared with 13 million from the Union of South Africa, including Southern Rhodesia, 15 million from Canada and 12 million tons from Australia.

Coal was known to exist on the Raniganj field in 1774 and was actually worked in 1777, though little was done in the way of regular mining until 1814. In those early days the coal was transported to Calcutta by boats on the Damodar river, and the completion of the East Indian Railway to Raniganj in 1855 really created the demand for the fuel. As the railway systems extended other fields were opened, and by 1881 production had reached about one million tons annually, though the imports of coal into India from abroad still averaged over 800,000 tons for the same period. Rapid expansion followed, the two million line was passed in 1890, the export trade began to develop, and by 1900 a yearly output of over six million tons was reached; imports had fallen to about 200,000 tons and exports increased to nearly half a million tons. (See Tables II, III and IV, pages 44, 45, 46.) Later statistics are arranged in tabular form below, and from them it is evident that uninterrupted progress was registered until 1919, with its record output of 22,628,037 tons. The decline which then set in was due to the cumulative effects of many post-war causes, shortage of railway

wagons, inadequacy of labour supplies, prolonged strikes and increasing imports. At the same time the collieries were for a period unable to meet the internal demand, and the prices obtained for good coals from 1920 to 1924 were the highest ever received: indeed in 1921 the domestic shortage became so acute that exports were temporarily prohibited. Production began to increase again in 1924, and in 1929 and 1930, reached fresh records of over 23 million tons, when the effects of the world's trade depression spread over the industry. Over the past few years prices have continued to slump, so that the 20 million tons raised in 1932 were only worth half the value at the pit head of the 19 million tons won a decade earlier. So serious has this long-continued fall in value become that proposals have recently been made amongst the coal producers to regulate production and control prices.

The total amount of coal and coke exported from India between 1900 and 1932 was 18,465,809 tons, of which Ceylon took 58·2 per cent, the Straits Settlements 19·2, Sumatra 6·1, Hongkong 4·9, Aden 2·7, the Philippine Islands and Guam 1·3, and other countries 7·5 per cent. In Table IV (page 46) the changes which have taken place in the destinations of the coal exports are shown. The trade reached its zenith in the pre-war quinquennium, when it approached a maximum of one million tons. In the post-war quinquennium coal from other countries gained a position in the Far Eastern markets which India formerly largely supplied, and the volume of her trade with them has never increased to its earlier size. A Coal Grading Board, constituted under an Act of the Indian Legislature in 1925, now arranges for the classification and certification of consignments of exported coal, so that overseas buyers may rely on the quality of the material supplied to them. The following grades fixed by the Board show the composition of various kinds of Indian coal generally:

#### LOW VOLATILE COALS

*Selected Grade.*—Up to 13% ash and over 7,000 calories or 12,600 B.T.U.s.

*Grade No. 1.*—Up to 15% ash and over 6,500 calories or 11,700 B.T.U.s.

*Grade No. 2.*—Up to 18% ash and over 6,000 calories or 10,800 B.T.U.s.

*Grade No. 3.*—All coals inferior to the above.

#### HIGH VOLATILE COALS

Up to 11% ash; over 6,800 calories or 12,240 B.T.U.s. and under 6% moisture.

Up to 13% ash; over 6,300 calories or 11,340 B.T.U.s. and under 9% moisture.

Up to 16% ash; over 6,000 calories or 10,800 B.T.U.s. and under 10% moisture.



The total imports of foreign coal into India between the years 1900 and 1932 amounted to 10,161,740 tons, of which 45·6 per cent came from the United Kingdom, 34·6 from South Africa, 7·8 from Australia, 6·1 from Japan and the remaining 5·9 per cent from other countries. The figures are analysed in Table III (page 45), the most striking features of which are the great decline in the imports from the United Kingdom and the corresponding rise in those from South Africa. Ocean-borne coals from Rhodesia are powerful competitors of Indian coals in the western markets of India itself and in seaports such as Colombo and Singapore. Although Indian coal exports now greatly exceed the imports, the position in Far Eastern countries in general is such that any striking increase in India's coal production is only likely to be realized by the development of her own internal market. The expansion of iron and steel metallurgy, the smelting of other metals, the opening of new railways and the growth of industry as a whole, will doubtless contribute their shares in the future, but the domestic market appears to offer more immediate attraction. The population of the Empire is over 352 million and its consumption of coal for household purposes has been estimated at only two million tons annually. Efforts are being made to popularize the use of soft coke in place of the traditional fuels of the home, and in 1929 legislation was enacted providing for the levy of a cess on soft coke dispatched by rail from collieries on the coalfields of Bengal, Bihar and Orissa. The funds so accumulated are used for promoting the sale and improving the methods of manufacture of soft coke, and some initial success has already been gained.

Over 98 per cent of the coal is mined from the Lower Gondwana rocks of the peninsula and the remainder comes from Tertiary strata of extra-peninsular regions. The chief Gondwana exposures are distributed in linear fashion along the valleys of the Damodar and Mahanadi, the Godavari and the Wardha. The former two converge, and coalescing in southern Baghelkhand continue to the west, on the lower side of the Narbada valley, hidden at intervals under the blanket of the later Deccan lava flows, until they finally disappear about Long. 78°. The coalfields are fragments, preserved mainly by faulting, of four great basins of fresh-water deposition which existed over these and probably much more extensive tracts, in Lower Gondwana (Permian) times. One such basin enclosed the areas now drained by the Son, Damodar and their tributaries, a second covered the

Chhattisgarh-Mahanadi region, a third the Godavari-Wardha valleys and the fourth, the Satpura region. Coalfields of Lower Gondwana age occur thus in the provinces of Bengal, Bihar and Orissa, Central India, the Central Provinces, Hyderabad and Madras, and will be dealt with in that sequence. (See Maps I and II.)

The actual amount of coal in the seams of the Lower Gondwana rocks of India, a total which may be regarded as reasonable, but nevertheless admittedly dependent on some uncertain data, was calculated by C. S. Fox in 1934 to be 60,000 million tons. Restricting the estimation to include only those seams which are over four feet in thickness, average 20 per cent of ash (not exceeding 25 per cent of ash on a moisture-free basis) and lie within 1,000 feet of the surface, the same authority reduces this total to 20,000 million tons, distributed as follows:

RESERVES OF WORKABLE COAL			<i>Million Tons</i>
1. Darjeeling foothills, Lisu-Ramthi area	...	...	20
2. Giridih, Jainti and Rajmahal hills	...	...	80
3. Raniganj, Jharia, Bokaro and Karanpura fields	...	...	10,150
4. Son valley—Hutar to Umaria and Sohagpur	...	...	2,000
5. Chhattisgarh and Mahanadi (Talchir)	...	...	1,200
6. Satpura region—Mohpani to Kanhan and Pench	...	...	150
7. Wardha-Godavari—Warora to beyond Singareni	...	...	6,400
Total			20,000

As regards reserves of good quality coal in seams upwards of four feet thick, an ash content of 16 per cent (moisture-free basis), and lying within 2,000 feet of the surface, the total is given as 5,000 million tons distributed as follows:

RESERVES OF GOOD QUALITY COAL			<i>Million Tons</i>
1. Giridih and Jainti	...	...	40
2. Raniganj	...	...	1,800
3. Jharia	...	...	1,250
4. Bokaro	...	...	800
5. Karanpura (North and South)	...	...	750
6. Hutar, Johilla, Burhar (Sohagpur)	...	...	50
7. Kurasia, Jhilmili, etc.	...	...	30
8. Talchir to Korba	...	...	200
9. Mohpani, Kanhan-Pench	...	...	30
10. Ballalpur-Singareni	...	...	50
Total			5,000

Chhattisgarh-Mahanadi region, a third the Godavari-Wardha valleys and the fourth, the Satpura region. Coalfields of Lower Gondwana age occur thus in the provinces of Bengal, Bihar and Orissa, Central India, the Central Provinces, Hyderabad and Madras, and will be dealt with in that sequence. (See Maps I and II.)

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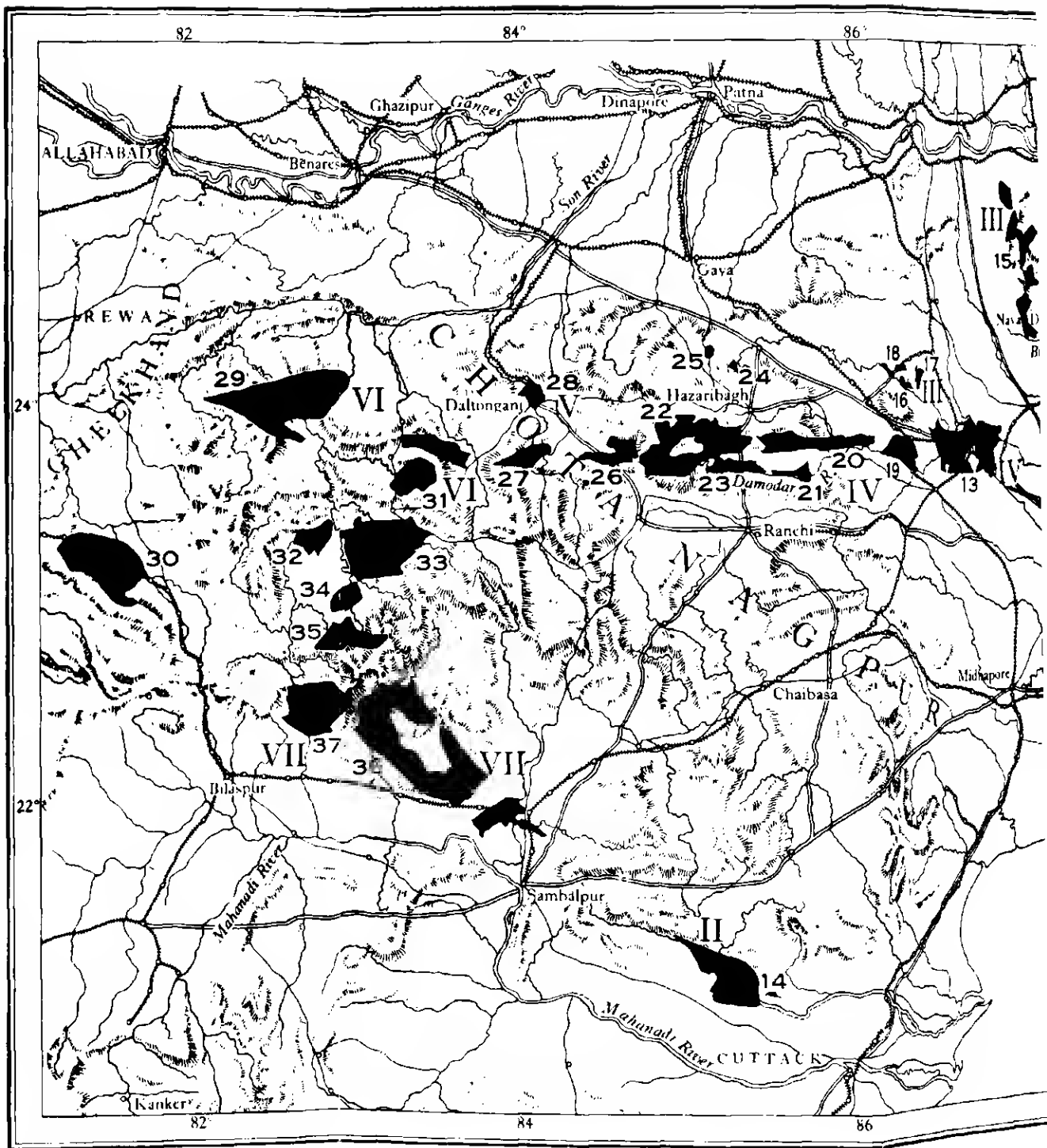
## RESERVES OF WORKABLE COAL

	<i>Million Tons</i>
1. Darjeeling foothills, Lisu-Ramthi area ...	20
2. Giridih, Jainti and Rajmahal hills ...	80
3. Raniganj, Jharia, Bokaro and Karanpura fields	10,150
4. Son valley—Hutar to Umaria and Sohagpur ...	2,000
5. Chhattisgarh and Mahanadi (Talchir) ...	1,200
6. Satpura region—Mohpani to Kanhan and Pench	150
7. Wardha-Godavari—Warora to beyond Singareni	6,400
Total	20,000

As regards reserves of good quality coal in seams upwards of four feet thick, an ash content of 16 per cent (moisture-free basis), and lying within 2,000 feet of the surface, the total is given as 5,000 million tons distributed as follows:

## RESERVES OF GOOD QUALITY COAL

	<i>Million Tons</i>
1. Giridih and Jainti ...	40
2. Raniganj ...	1,800
3. Jharia ...	1,250
4. Bokaro ...	800
5. Karanpura (North and South) ...	750
6. Hutar, Johilla, Burhar (Sohagpur) ...	50
7. Kurasia, Jhilmili, etc. ...	30
8. Talchir to Korba ...	200
9. Mohpani, Kanhan-Pench ...	30
10. Ballalpur-Singareni ...	50
Total	5,000



*India's Mineral Wealth*, facing p. 12.

Map I

COALFIELDS OF BENGAL, BIHAR, ORISSA, CENTRAL INDIA AND THE CENTRAL PROVINCE

After R. R. SIMPSON.

From *Memoirs, Geological Survey of India*.

Of coal suitable for the manufacture of metallurgical coke, to be used in the smelting of iron and other ores, the reserves are tentatively placed at 1,500 million tons, in Giridih, Raniganj, Jharia, Bokaro and Karanpura. No deductions are made in these estimates for losses associated with mining, but earlier extractions have been deducted.

## LOWER GONDWANA COALFIELDS

### BENGAL, BIHAR AND ORISSA

The coalfields of Bengal, Bihar and Orissa have accounted for 90 per cent of the 530½ million tons raised in India between 1900 and 1932. They are isolated fragments of the once continuous Gondwana land, faulted down into the crystalline floor and arranged in a band stretching roughly east and west along the Damodar valley. (See Map I.)

*Raniganj.* The easternmost of the group, Raniganj, is from 120 to 140 miles north-west of Calcutta and has an area of 600 square miles. It was the first coalfield to be worked in India (1777) and until 1905 was the leading producer. In 1906, its output, then 37 per cent of the Indian total, was surpassed by that of Jharia, with 42 per cent. In 1932 it yielded 6,419,007 tons, or 31·85 per cent of the total, and from 1815 to 1932 the tonnage raised has been of the order of 200 millions. Its Lower Gondwana rocks are divided in ascending order into the Talchir series, the Damudas and the Panchet series. The coal-bearing Damuda group is subdivided as follows:

3. Raniganj Series, 3,400 feet thick, containing the Sitarampur and Nituria coal measures.
2. Ironstone Shales, 1,200 feet thick.
1. Barakar Series, 2,100 feet thick, with the lower and middle Barakar coal measures and the Begunia seam.

These rocks are believed to range from Lower to Upper Permian in age. Important coal seams include the Dishargarh (18 feet thick), Sanctoria (10 feet), Sibpur (12 to 18 feet), Ghusic (12 feet) and Raniganj (15 feet), while the workable seams of the Barakar or Lower Measures, at Chanch, Laikdih, Ramnagar and Salanpur, average 20 feet in thickness. An exhaustive account of the field was published in 1932 by E. R. Gee. In the Lower Measures he has correlated seven, and in the Upper (Raniganj) ones, ten seams, or groups of them which

differ in properties as they do in geological position. Coals of Barakar age have relatively low moisture, ranging usually from 1 to 3.5 per cent; comparatively low volatile contents, from 21 to 30 per cent, as a rule, and a high proportion of fixed carbon, from about 52 to 64 per cent, a figure about 55 per cent being common. The better quality Barakar fuels are excellent steam coals and tend to form hard cokes. Raniganj or Upper Measure coals, on the other hand, have more moisture, ranging from 3 to 10 per cent (though the Dishargarh seam often contains only 1.35 to 3 per cent) and high volatile contents, ranging in the better grades from 29 to 38 per cent. With the exception of the Dishargarh and Sanctoria seams, they are either non-caking or produce a very soft coke. They are excellent gas coals and free-burning steam raisers. Gee has estimated the reserves of the Raniganj field as follows:

		TO A DEPTH OF 1,000 FT.	TO A DEPTH OF 2,000 FT.
		<i>Tons</i>	<i>Tons</i>
Caking Coal of Superior Quality ...	...	81,791,000 <sup>1</sup>	249,905,000
Non-Caking Coal of Superior Quality ...	...	963,644,000	1,570,730,000
Coal of Inferior Quality ...	...	4,631,142,000 <sup>2</sup>	6,859,291,000

Shafts have recently been sunk on the Raniganj field to depths of nearly 1,500 feet and are thus the deepest coal mines in India.

*Jharia.* The Jharia field, with an area of 175 square miles, lies 16 miles farther west, and although coal was known to occur here before 1858, mining was not seriously undertaken until 1894 when the railway arrived. From that time production has risen from 15,000 tons to a maximum of over 12,100,000 tons in 1919, or 53.68 per cent of the Indian output for that year. In 1932, 8,551,283 tons were raised and the total yield to the end of that year was 259,371,830 tons, omitting the two years 1895 and 1896, for which separate figures are not available.

As in the case of Raniganj, the Damudas are divided into three main divisions which, together with their subdivisions recently

<sup>1</sup> Includes coal which yields good metallurgical coke without admixture and reserves of good coal which when mixed with a strongly caking, low volatile coal have proved to yield a hard coke.

<sup>2</sup> Limited to seams and portions of seams of proved economic value.

proposed by C. S. Fox in his important monograph on the field (1930), are tabulated below:

RANIGANJ SERIES	Lohpiti Sandstone Stage	...	...	...	No coal
	Telmucha Stage	...	...	...	Coal seams
	Jamdih Sandstone Stage	...	...	...	No coal
	Murulidih Stage	...	...	...	Coal seams
BARREN MEASURES SERIES	...	...	...	...	No workable coal seams found
BARAKAR SERIES	Bhagaband Stage	...	...	...	Seams XVIII, XVII and XVI
	Jialgara Stage	...	...	...	Seams XV, XIV-A, XIV and XIII
	Gareira Stage	...	...	...	Seams XII, XI, X, IX and VIII
	Muraidih Stage	...	...	...	Seams VII, VI, V, IV, III, II and I

The Barakar series contains not less than 24 separate seams with not less than four feet of coal in each, twelve of which are workable, and six of which are of considerable value and often of great thickness. The total thickness of the series is about 2,000 feet, the coal in all the seams probably exceeds 200 feet, while the workable sections are said to average 75 feet in thickness in the eastern half of the field. Typical analyses of coals from each of the stages are given below.

#### ANALYSES OF JHARIA COALS

	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	CALORIFIC VALUE
Telmucha Stage	2.11	28.40	52.80	18.80	6,607
Murulidih Stage	2.20	27.68	57.20	15.12	7,403
Bhagaband Stage	1.80	28.80	59.30	11.09	7,209
Jialgara Stage	1.59	24.00	62.40	13.60	7,403
Gareira Stage	0.70	18.75	63.05	18.20	6,882
Muraidih Stage	0.65	14.20	68.00	17.80	7,141

The seams of the Upper Barakar stages, Bhagaband and Jialgara, Nos. XV, XIV-A, and XIV with XVII and XIII as well as XVIII and XVI, in the order named, are probably the most valuable coals available in India for public supply. They are banded, bright and dull coals of better quality than any other Gondwana coals, according to Fox, with the exception of the lower Karharbari seam of the Giridih field. They are coking varieties and from them metallurgical coke for the iron and steel furnaces is made. Fox has estimated the reserves of the Jharia field as follows:

SEAMS OF	MILLIONS OF TONS AT DEPTHS OF		
	500 Ft.	1,000 Ft.	2,000 Ft.
Telmucha Stage ... ..	17	29	29
Murulidih Stage ... ..	36	61	61
Bhagaband Stage ... ..	115	225	225
Jialgara Stage ... ..	293	568	731
Gareira Stage ... ..	580	1,100	1,550
Muraidih Stage ... ..	630	1,103	1,575
Extras ... ..	36	36	36
Total ... ..	1,707	3,122	4,237

Owing to the waste associated with existing mining methods Fox believes that the reserves of the Bhagaband and Jialgara stages to a depth of 1,000 feet, on which the life of the field largely depends, as far as good quality coking coals are concerned, must at the present rate of extraction be exhausted within 40 to 50 years, and he has advanced cogent arguments in favour of an active policy of conservation, as they are by far the most valuable reserves of coal known in India at present.

*Bokaro.* Two or three miles west of Jharia lies the Bokaro field, with an area of 220 square miles. Its coals are confined to the Barakars, as workable seams have not been discovered west of Jharia in the younger Raniganj Series. By 1910 three collieries were under development on this field and its output jumped from 10,000 tons to nearly 200,000 tons per annum on the approach of the railway in 1916, through communication being established in 1919. Over one million tons, being 5.46 per cent of the total production for that year, were won in 1922. Its record output was 2,160,249 tons, or 9.07 per cent of the total in 1930, but this fell to 1,348,973 tons in 1932. The total raised from the field to the end of that year was 21,207,298 tons. Several seams are known, some of them of great thickness, ranging up to a maximum of 126 feet of solid coal. In 15 square miles the total reserves of all kinds are estimated as at least 3,000 million tons. Both the Bokaro and Kargali seams are known to be of good coking quality and the reserves of this type probably total 600 million tons. Plate II, a photograph by C. S. Fox, reproduced with the permission of the Director, Geological Survey of India, shows Quarry No. 7 on the Bokaro field and illustrates the open cast method adopted in mining these great seams.





OPEN CAST MINING IN A THICK SEAM OF THE BOKARO COALFIELD

*Ramgarh.* The small field of Ramgarh, with an area of 40 square miles, lies about 5 miles south of Bokaro. It contains three thick seams of poor coal. Its output up to date has been insignificant.

*North and South Karanpura.* The extensive coalfields of North and South Karanpura, with areas of 472 and 72 square miles respectively, are situated in the upper part of the Damodar valley. Mapped by T. W. H. Hughes in 1867-68, they were re-surveyed by A. Jowett in 1915-18. Very large quantities of coal of Barakar age have been proved, and remarkably thick seams, up to a maximum of 90 feet, occur. Together the fields are believed to contain 9,500 million tons. Excellent coke is said to have been made from mixtures of the Sirka-Argada seam and certain Jharia coals. Production commenced in 1925 and rose rapidly with the provision of railway communication to a maximum of 482,141 tons, or 2 per cent of the Indian output, in 1930. The output in 1932 was 409,566 tons, and the grand total from the fields, 2,610,240 tons. Only three collieries are at work at present, but the fields will doubtless supply an increasing share of India's requirements in the future.

*Chope and Itkhori.* Lying to the north of the Karanpura fields and on the Hazaribagh plateau are the two, tiny undeveloped coal-fields of Chope and Itkhori. The coal-bearing Barakar rocks cover less than one square mile in the former and about half a square mile in the latter.

*Sahajuri, Jainti, and Kundit Karaia.* Forming as it were outliers to the great fields of the Damodar valley proper, and actually in the valley of the Adjai river and in that of the Baraker, itself a tributary of the Damodar, are the coalfields of Sahajuri, Jainti, Kundit Karaia and Giridih. The three first named have a combined area of about  $28\frac{1}{2}$  square miles of which  $11\frac{1}{2}$  are occupied by Barakar rocks. The opinion of T. W. H. Hughes in the case of Jainti, that in any summary of the coal resources of India it must occupy a very subordinate position, probably applies equally well to all. Coal was obtained from Jainti in 1886, but organized mining dates from 1914. The record output was reached with 152,941 tons in 1919 (0.69 per cent of the Indian total). The total production to 1932 is 1,462,538 tons and that for 1932 was 43,163. It has three workable seams, partly of good quality.

*Giridih.* The Giridih coalfield was brought to notice by McClelland in 1848, and though its area is only about 11 square miles, of which 7 are occupied by Barakar rocks, it is of great importance by reason of its position and the fact that it yields some of the best coal in India. Systematic mining was initiated in 1851, and the geological survey undertaken by Hughes in 1868. A railway reached it in 1871 and since that time exploitation has been vigorous. The principal seams are the Lower Karharbari (average thickness 15 feet 4 inches), the Upper Karharbari (6 feet) and the Bhaddoah (6 feet). Other seams possess an aggregate thickness of 66 feet, but much of this is of poorer quality. The coal has a high thermal value and the best metallurgical coal made in India comes from it. The whole of the lump coal is used on locomotives by the State Railways, while the slack is converted into coke. Slack coal is imported from other fields to the Giridih mines for their own purposes, in much the same way as fuel oil from Persia is burnt to raise power on the Yenangyaung oilfield in Burma. In 1928 the total reserves of all kinds were estimated at 60 million tons, of which 30 million in the Lower Karharbari seam alone are capable of giving excellent coke. By 1880 the output of the field had reached the neighbourhood of 400,000 tons and its production in normal recent years has been double that quantity. Its highest record was 950,045 tons, or 4.2 per cent of the Indian total, in 1919. From 1900-32, 25,436,999 tons were raised.

*Rajmahal Hills.* To the north of the Damodar valley, coal measures of Barakar age are exposed over 70 square miles in five separate areas, named Hura, Chaparbhita, Pachwara, Mahuaga and Brahmini, on the western margin of the Rajmahal hills. The reserves of coal of poor quality are believed to be large; thus in 1869-70, V. Ball estimated that 210 million tons could be easily won. Attention has been directed to the fields from time to time, but exploitation is confined to the extraction of small quantities of coal for local uses from outcrop quarries. The production in 1932 was 1,500 tons.

*Aurunga, Hutar and Daltonganj.* The main belt of the coalfields of the Damodar valley is continued west into that of the Koel river and its tributaries, itself an affluent of the Son, and within the Palamau district of Bihar. Aurunga, surveyed by Ball in 1878 and

Dunn in 1928, is 97 square miles in extent, of which the coal-bearing Barakars occupy  $58\frac{1}{2}$  square miles. Numerous coal seams occur and some of them are of considerable thickness, but the quality of the exposed coal is very poor. Hutar is 12 miles west of Aurunga. It was also investigated by Ball in 1878 and the coal measures proved to occupy 57 square miles. Five seams, from 1 to 13 feet 8 inches in thickness, occur but the area they cover has not been worked out. J. A. Dunn (1929) calculated that two of them, measured over an area of four square miles, contain 32 million tons. The coal is of average Indian quality. In the Daltonganj field the Barakars cover about 30 square miles and coal was known to occur in 1829. Collieries were commenced soon after 1840, and in 1872 the field was examined by Hughes, though the railway did not reach it until 1901. Several seams of medium thickness occur, but the coal is not of the first quality and does not coke. According to La Touche (1891) about nine million tons of fair quality existed in an area of one square mile near Rajhara. For many years, the production maintained was between 70,000 and 80,000 tons per annum; the record year was 1908 with 96,391 tons, being 0.76 per cent of the total. Fifteen years ago, however, output began to fall away and is now quite insignificant.

*Talcher.* The Talcher coalfield which belongs to the Mahanadi-Gondwana belt, lies in the valley of the Brahmani river in Orissa, some 65 miles north-west of Cuttack. It was surveyed with disappointing results in 1855 and has the distinction of forming the subject of the first memoir published by the Geological Survey of India. A systematic drilling campaign in 1919, however, proved the existence of large quantities of coal in several seams and the reserves are now stated to be about  $184\frac{1}{2}$  million tons. The field is much nearer to the Madras Presidency than any other in the provinces of Bengal or Bihar and Orissa, a position which may make it a factor in the future sources of supply for Southern India, especially as it is in communication with the main railway line to the south. Production commenced in 1923, the record output was 253,586 tons (1.26 per cent of the Indian total) in 1932, and the total tonnage raised up to the end of that year was 604,798 tons.

*Rampur (Raigarh-Hingir).* The Rampur, Sambalpur, or Raigarh-Hingir coalfield lies partly in the Sambalpur district, but crosses the

provincial boundary into the Raigarh State of the Central Provinces. C. S. Fox in 1934 proposed to divide it into the Raigarh, Raigarh South, Hingir and Ib River fields. Early surveys by V. Ball of part of its area of some 300 square miles, in 1871 and 1875, and systematic borings under official auspices in 1884-86, were not particularly encouraging, though thick seams of inferior coal were proved. The accidental discovery of a coal seam in sinking for a railway bridge foundation, led to a re-survey by G. F. Reader in 1900, when four seams varying from four to seventeen feet in thickness were found by boring. The Ib bridge seam, however, was the only one with a low enough ash percentage to be worth working. In 1934, C. S. Fox calculated that it contains at least 140 million tons within a depth of 600 feet from the surface. Mining commenced in 1909. The highest production was reached with 77,277 tons (0.40 per cent of the total output) in 1921, but of late years the tonnage raised has averaged about 34,000 tons annually, falling to 19,498 tons in 1932. The total amount of coal taken from the field up to the end of that year was 941,223 tons.

*Darjeeling.* Coal-bearing rocks of Damuda age occur in the Outer Himalayan ranges of the Darjeeling district and of other regions farther eastwards. Many seams, varying in thickness from two to eleven feet, were found by F. R. Mallet in 1874 in the 30 miles' stretch of country between Pankabari and Daling. The coal itself, however, is in a very powdery condition, though Bose's later researches in 1890-91 proved that some of it possesses coking properties.

#### CENTRAL INDIA

Of the 530,612,935 tons of coal raised in India during the present century, 5,969,445 tons or 1.12 per cent were derived from the two producing fields of Central India, Umaria and Sohagpur. These and the three unopened coalfields briefly described below, lie within the jurisdiction of the Rewah State. (See Map I.)

*Umaria.* Umaria is situated on the Umrar river, a tributary of the Son, 36 miles from Katni, and was surveyed by Hughes between 1881 and 1884. It has an area of 6 square miles, but the Barakar coal measures, which contain six seams, dip under younger rocks and may be continuous with those of the Korar field, three

miles away. Mining commenced in 1884 and has been carried on in four seams, measuring from 3 to 12 feet thick. The available reserves over a portion of the field were estimated at 55 million tons in 1885. C. S. Fox in 1934 estimated the future available supply at 24 million tons. The largest recorded annual output was 200,285 tons, or 1.16 per cent of the total for that particular year, in 1916. Since then there has been a steady decline, compensated since 1921 by the increasing quantities won from the Sohagpur field, and in 1932 Umaria only supplied 74,293 tons. Between 1884 and 1932 the total production was 5,848,599 tons, including the Johilla output between 1898 and 1902.

*Korar.* The small, undeveloped field of Korar surveyed by Hira Lal and Hughes in 1882, has an area of  $9\frac{1}{2}$  square miles, in which four seams ranging from four to eight feet in thickness, have been proved by boring.

*Sohagpur.* Sohagpur is the largest of the coalfields of Rewah and as mapped by Hughes in 1880, it covers 1,600 square miles, but portions of it which cross into the Korea State of the Central Provinces have been separated under the names of the Sanhat and Jhagrakhand fields. This reduces the area to about 1,200 square miles. Nine-tenths of this is covered by Barakar rocks, and details of the outcrops of coal have been given both by Hughes and K. P. Sinor (1923). As far as available information goes, the seams are neither abundant nor thick, but their low dips and great extent counterbalance this, and there is little doubt that when detailed estimates are made they will be very large figures. The south-western section has railway connexion, and mining operations commenced in the Burhar-Amlel area in 1921, where the normal thickness of the coal is stated to be 10 feet. Sohagpur, with an output of 131,174 tons, passed the Umaria production in 1924 and reached its highest figures of 166,195 tons (0.82 per cent of the total) in 1932. Its total raisings are 1,211,183 tons to the end of 1932.

*Johilla.* In the Johilla field the coal measures occur in two separate tracts, covering together an area of  $14\frac{1}{2}$  square miles, in which Hughes thought there were quite 20 feet of coal from which at least 100 million tons might be available within a depth of 500 feet. C. S. Fox, however, reduced this to 30 million tons in 1934. Later borings

have been encouraging and the field is regarded by the State as a valuable reserve.

*Singrauli.* The area of the Singrauli field, surveyed by R. D. Oldham and P. N. Dutta, and later examined by K. P. Sinor and A. L. Coulson, covers about 900 square miles, and it extends from the Rewah State into the south-western corner of the Mirzapur district of the United Provinces. Several coal seams are known, including two of 6 and 18 feet in thickness, respectively, near Parari and Naunagar. Many years ago small amounts of coal used to be extracted and carted to Mirzapur for the Ganges river steamers, but in more recent times the field has attracted no attention.

### CENTRAL PROVINCES

The producing coalfields of the Central Provinces raised 2.75 per cent of the Indian production during the present century, or in exact figures, 14,578,807 out of a grand total of 530,612,935 tons. They are best described in four separate groups which include those portions of the Rewah-Gondwana basin stretching across into the Central Provinces; those fields lying for the most part in the valleys of tributaries of the Son, and which form, as it were, a line joining the western prolongation of the Damodar valley fields to those of the Brahmani-Mahanadi line; the fields of the Satpura region and, finally, the Wardha valley group. (See Maps I and II.)

### GROUP I

The accident of a political frontier divides part of the coalfields of the Rewah-Gondwana basin which lie in Central India from their neighbours in the Central Provinces. These are known as Sanhat, Jhagrakhand, Kurasia and Koreagarh.

*Sanhat.* The Sanhat coalfield is the name given by L. L. Fermor (1913) to the eastern extension of the Sohagpur field which is included in Korea State. It has an area of about 330 square miles and contains two principal seams. The lower of these is valueless in the western half but ranges from 4 to 9 feet in thickness over a length of 16 miles, in the east. The upper seam is worthless in the east, and from 3½ to nearly 10 feet thick in the west. Neither is of good quality.

*Jhagrakhand.* The Jhagrakhand field is a small area of 22 square miles formed by the extreme south-eastern corner of the Sohagpur field, projecting into Korea. It was re-examined by A. L. Coulson in 1923, who described three coal-bearing horizons. The lowest is the most important: extending over four or five square miles it has about 30·8 million tons of good coal available per square mile, while its two seams average 4 and 6 feet thick respectively, with a parting of 13 to 28 feet. In the second horizon the coal appears to be of lower grade. The lateral extent of the highest is small and its seams thin.

*Kurasia.* The Kurasia field is a detached area of 48 square miles, lying four to six miles south of the central part of the Sanhat field. Here, according to Fermor, there are six coal-bearing horizons in the Kurasia section. The principal seam ranges from a foot to 8½ feet thick and probably covers four square miles, with 5½ million tons per square mile. Better coal is found in the Chirmiri section, in which seven seams aggregating 38 feet, and in which a minimum of 7 million tons per square mile, rising possibly to 20 or 30 million tons of coal of good quality, are available. Production commenced in 1930, and up to the end of 1932, 148,726 tons had been won.

*Koreagarh.* Koreagarh, with an area of six square miles, is three miles south-east of Kurasia and three seams of medium grade are reported to occur in it.

## GROUP II

In the next group the fields concerned, commencing from the south, are the Mand River in Udaipur State, Korba in the Bilaspur district; Rampur, Lakhanpur, Bistrampur and Ramkola-Tatapani in the Sirguja State and Jhilmili in the State of the same name. The fields are not developed and can only be briefly referred to here.

*Mand River.* The Mand River field, described by V. Ball in 1871, lies within eight miles of the western limits of the Rampur (Raigarh-Hingir) field. It has an area of about 300 square miles, over which a large number of coal seams exist. Borings in 1886 only proved material of too low a grade for profitable exploitation.

*Korba.* The Korba field is situated in the valley of the Hasdo river and covers more than 200 square miles. In 1870, Blanford found an



outcrop exposing 50 feet of coal of good quality. Borings in 1887 proved the Korba seam to be 69 feet thick, but it consisted of alternations of poor coal and carbonaceous shale, though more promising seams are also known. More recent work has proved some 50 million tons of good coal and upwards of 200 million tons of inferior grade in this field, which, lying within 24 miles of the main Bengal-Nagpur Railway, will doubtless be developed in due course.

*Hasdo-Rampur.* The Hasdo-Rampur field has an area of 400 square miles, according to C. S. Fox (1934), and is known to contain several seams of varying quality. The coal measures of its eastern and south-central sections pass under younger rocks and appear again in the Mand River and Korba fields.

*Lakhanpur.* Lakhanpur lies partly in Sirguja and partly in Bilaspur district. Its area is 135 square miles, in which several outcrops of seams from 3 to 9 feet thick have been found. Its outliers of Sendurgar (20 square miles), Panchbhaini ( $4\frac{1}{2}$  square miles), and Damhamunda ( $4\frac{1}{2}$  square miles), are sometimes referred to as separate fields.

*Bisrampur.* In the Bisrampur field of Central Sirguja, Ball (1872) found the coal measures extending over 400 square miles with good coal in fair abundance but, like most of the other fields of the Chhattisgarh Feudatory States, it will have to be geologically surveyed on a large scale and bored before reliable estimates of its resources can be made. Five miles to the east of Bisrampur is the small field of Bansar, in which one thin seam is known.

*Ramkola-Tatapani.* The coal measures of the Ramkola-Tatapani region occupy about 100 square miles in north-east Sirguja passing as they do in many of these fields under deposits of younger rocks. They were examined by Griesbach, in 1878-79, and found to contain numerous seams, but few of them are of workable thickness or quality. The Morne River seam varies from  $3\frac{1}{2}$  to 17 feet in thickness, and has been followed for more than a mile.

*Jhilmili.* The Jhilmili field has an area of about 40 square miles in which the coal measures occur in three strips. According to A. L. Coulson (1923), there are four coal-bearing horizons in the southern one, while in the central area, four have been found and more probably exist. There are indications of coking coal of good quality, but no estimates are possible until the field is bored.

## GROUP III

Between the isolated Mandla mass of Deccan Trap on the east and its main great expanse on the west, lie the Gondwana rocks of the Satpura region, in which coal measures appear at intervals under the margins of the younger groups, for a distance of 170 miles; particularly on the north near Mohpani, in the Narsinghpur district, and on the south in the Betul and Chhindwara districts. The coalfields concerned are the following: Mohpani in the Narsinghpur district; Shahpur in the Betul district; and Tawa River (partly in Betul), Kanhan Valley and Pench Valley, in the Chhindwara district.

*Mohpani.* The exposed coal measures (Barakars) of Mohpani, the most northerly of these fields, cover rather more than one square mile. Originally discovered by J. R. Ouseley in 1835, mining commenced in 1862 and continued in the four seams of an area known as the 'old field' until 1902, the total amount raised being 450,845 tons. In 1892, a second area, the 'new field', was discovered as a result of the work of F. L. G. Simpson and T. D. La Touche, in which seams, aggregating 27 feet in thickness, spread over a considerable expanse. Up to the end of 1903 when the mines were sold to a railway company, the output from this had been 181,080 tons, and from that date until the mines were closed in 1926, a further 1,402,987 tons were obtained. The highest production was reached in 1921, with 89,623 tons, or 0.47 per cent of that year's total. The coal was somewhat inferior in quality to the average Damodar valley coal, and for locomotive purposes  $1\frac{1}{4}$  tons of Mohpani coal were taken as equivalent to 1 ton of Bengal coal.

*Shahpur.* The Shahpur fields, with an exposed area of about 26 square miles, lie in the valley of the Tawa river between Betul and Hoshangabad, and their thin coal seams were first noticed by J. Finnis in 1834. J. G. Medlicott in 1863, and Blanford in 1868 found numerous narrow seams, and H. B. Medlicott surveyed the field in 1875, but found nothing likely to be profitable. Borings in 1881 led to no better results. Small quantities of outcrop coal have been removed for local uses from time to time; thus in 1923, 2,063 tons were so taken, but even this apparently ceased in 1927. Other small areas of Barakar rocks occur in the Tawa valley, the most important of which, Pathakera, is 16 square miles in extent and contains three seams up to 10 feet thick.

The fields of the Chhindwara district lie on the southern flanks of the Satpuras in the valleys of the Tawa, Kanhan and Pench, the exposed measures covering about 100 square miles and stretching from close to the Shahpur field in the west, in an easterly direction for 50 miles, to a point 10 miles north of Chhindwara itself. They were discovered by Lt. Jerdon and R. H. Sankey in 1852, described by W. T. Blanford in 1866, A. Sopwith in 1867 and E. J. Jones in 1887.

*Tawa.* In the Tawa area, which crosses into Betul district and covers about 79 square miles, a seam 5 feet thick crops out near Tandsi.

*Kanhan Valley.* The Kanhan Valley fields, following the classification proposed by C. S. Fox in 1934, include from west to east, the Damua-Kalichhapar, Ghorawari-Nimkhera, Panara-Jinnaur, Datla-Jamai and Hingladevi areas. Three or four seams of workable thickness are present, but only the top one is thick and good enough to mine profitably at present. The coal is of fair coking quality and there are workings on each area, the region having been opened by railway extensions in 1915. The production is included in that of the Pench Valley fields. The coal measures (Barakars) are severely faulted and estimates of reserves have not been made.

*Pench Valley.* The coal measures of the Pench Valley field are exposed over about  $7\frac{1}{2}$  square miles. Several seams crop out at the surface, and one of good quality, 6 feet thick, was quarried about 1862. Encouraging prospecting operations by private firms in 1904 were followed by railway communication in 1905. A narrow strip of Barakar coal measures extends eastwards from Barkuhi through Chandameta and Parasias to the Pench river near Chhinda, a distance of ten miles as the crow flies. There are also disconnected areas of coal measures in the neighbourhood, eastward from Eklair, near Harrai, at Sirgora and other places. The first colliery was started at Chandameta near Parasias in 1905 and the areas most actively exploited at present are those between Barkuhi and Rawanwara and the strip eastwards from Eklair. Although several coal seams occur, only four are regarded as workable and only one, from 5 to 12 feet thick, is actually mined. In part of the western end of the field, C. S. Fox has recently estimated that  $15\frac{1}{2}$  million tons of coal are still available. From the commencement of operations in 1903 until the end of

1932, the Pench Valley coalfield has supplied a total of 8,731,807 tons of coal. Progress has been practically continuous, and output doubled in the seven years between 1927 and 1932, when it reached its highest figures of 831,817 tons, or 4.13 per cent of the Indian total.

#### GROUP IV

The Wardha valley coalfields are situated in the Chanda and Yeotmal districts and form part of the Godavari-Gondwana belt. R. R. Simpson has summarized the occurrences as follows: 'They occupy the valley of the Wardha river for a distance of about 72 miles in a straight line, the total area being 1,600 square miles. The coal-bearing rocks (Barakars) have a thickness of only 250 feet, and their distribution is very broken and their surface area small. There appears to be only one coal horizon, and it occurs near the top of the coal measures. The thickness of the coal varies from nothing up to 90 feet, the average being about 30 feet. Our knowledge of the fields is almost entirely due to T. W. H. Hughes, who between 1870 and 1876 mapped the area and superintended the boring operations.' In the Chanda district are situated the Bandar, Warora, and Ballalpur fields, the last crossing into Hyderabad territory. In the Yeotmal district there are the fields of Wun and its related areas. The Ghugus-Telwasa fields lie partly in both districts.

*Warora.* The coal measures of the Warora basin, which is 62 miles south of Nagpur, are largely overlain by younger rocks and alluvium. Borings in 1870 proved two seams averaging 12 and 15 feet, over 420 acres. Collieries were worked between 1873 and 1906, and after raising about three million tons were abandoned owing to mining difficulties. Hughes estimated the reserves in 1877 as 20 million tons, with probable extensions to the south raising the total to 60 or 100 million tons. The coal is inferior to Raniganj coal owing to its higher moisture and lower fixed carbon contents.

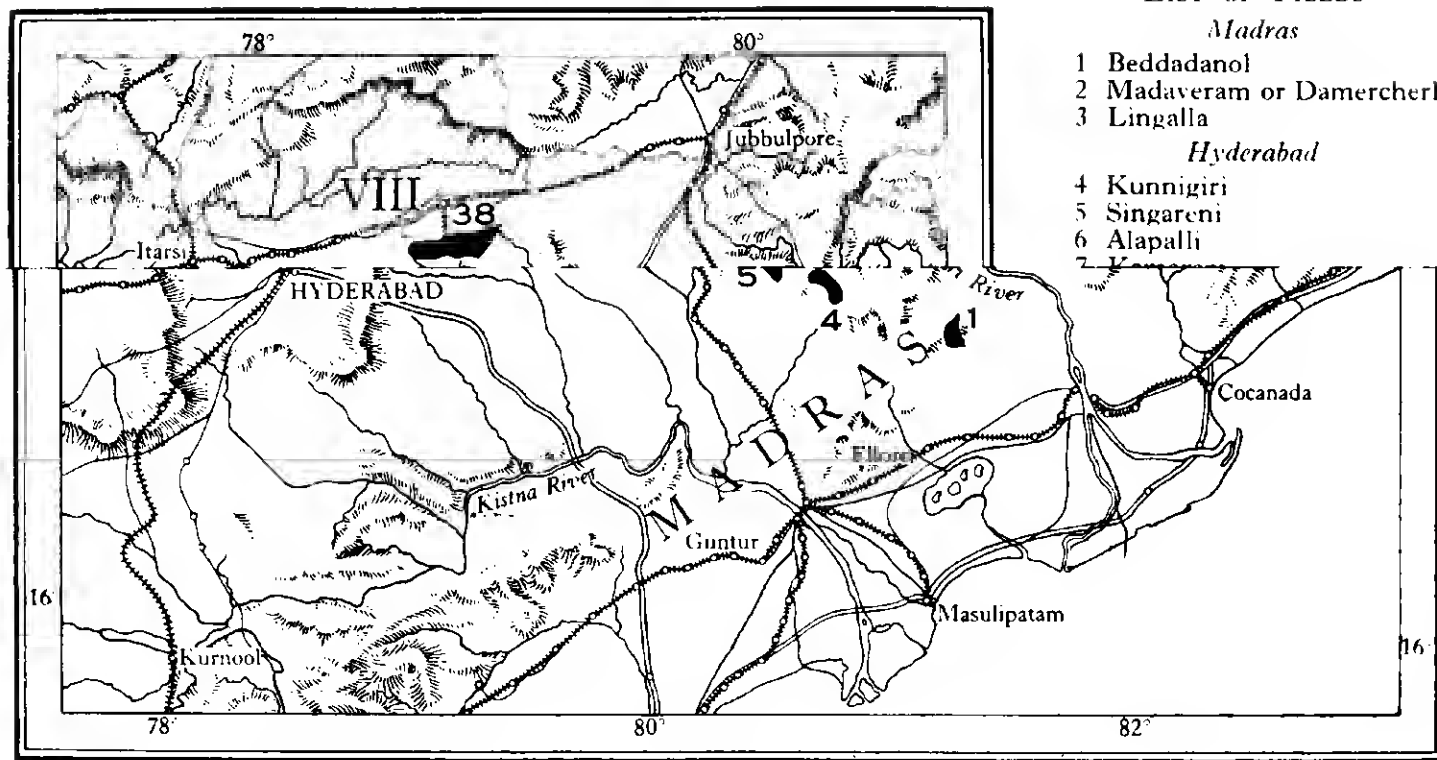
*Ghugus-Telwasa.* The Ghugus-Telwasa field of small extent as far as outcrops are concerned, is in reality a concealed field of about 100 square miles, in which C. S. Fox in 1934, estimating on a seam of 15 feet in thickness, concluded there are 1,000 million tons of available coal. A small colliery was worked here for a few years from 1870 onwards, and other mines have been operated in more recent times,

whose output is apparently included with that of Ballalpur in the official returns.

*Bandar.* The Bandar field of about six square miles is 30 miles north-east of Warora, and seams with an aggregate thickness of 17 feet have been proved by boring over one square mile. C. S. Fox (1934) estimated available reserves of at least 54 million tons. The field is isolated and undeveloped.

*Ballalpur.* The Ballalpur field lies mainly in Hyderabad where it is known as the Sasti field. In 1868, Blanford found a seam 6 feet thick on that side of the Wardha river, but borings on the British side at that time failed to reach it. In anticipation of the closure of Warora colliery, re-boring in this vicinity was undertaken and a seam 52½ feet thick proved over 1½ square miles, with reserves of 36 million tons. Two shafts reached this coal in 1906 and railway connexion was established in 1908. The total amount of coal won up to the end of 1932 is 3,287,723 tons, the record output of 223,025 tons (1.03 per cent of the total production) was made in 1931, and the figure for 1932 was 217,421 tons. Covered by younger rocks, the exact limits of the coal measures are unknown. In the two square miles proved there are reserves of 40 million tons, but the total area involved may well be 200 square miles with a corresponding multiplication of the figures. Coal has also been mined in Chanda itself while another large area exists around Wamanpalli, where further concealed coal measures occur.

*Wun and Related Areas.* 'On the Wun side of the Wardha,' wrote Hughes, 'a much larger area has been tested than on the Chanda side and the coal has been proved to be much less irregularly distributed. An average of 20 feet may be admitted for 20 square miles and 30 feet for 60 miles, making a total of 2,100 million of tons.' From direct evidence 105 million were estimated to occur between Wun and Papur (7 square miles), and 150 million in 5 square miles between Junara and Chicholi, all within 500 feet of the surface. Exploratory shafts at Pishaon proved a seam 21 feet thick. Reviewing the evidence in 1934, C. S. Fox calculated the existence of 240 million tons in 12 square miles from beyond Pishaon to Warora, of which half may be considered available. A total of 13,489 tons of coal was removed from the Yeotmal district between 1920 and 1927.



# LIST OF FIELDS

## Madras

- 1 Beddadanol
- 2 Madaveram or Damercherla
- 3 Lingalla

## Hyderabad

- 4 Kunnigiri
- 5 Singareni
- 6 Alapalli
- 7

India's Mineral Wealth, facing p. 28.

Scale, 1 inch = 64 miles.

## Map II

### COALFIELDS OF THE NIZAM'S DOMINIONS AND THE CENTRAL PROVINCES (IN PART)

After R. R. SIMPSON.

From *Memoirs, Geological Survey of India*, XLI, with Director's permission.

## COMPOSITION OF CENTRAL PROVINCES COALS

(Tabulated by L. L. Fermor)

	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	SULPHUR	AVERAGE OF
<i>Satpura Coalfields—</i>						
Mohpani, Coal ...	2.52	24.26	48.71	24.01	0.50	10 samples
Mohpani, Splint ...	2.84	20.55	37.42	38.24	0.95	...
Barkuhi Field (Pench) ...	...	22.8	53.6	23.6	...	3 "
Barkuhi " " ...	1.73	24.07	52.59	21.61	0.73	1 "
Sirgora ...	...	28.0	61.6	10.4	...	...
<i>Chhattisgarh Coalfields—</i>						
Sanhat, Lower Seam ...	5.79	28.22	44.80	21.19	...	3 "
Sanhat, Upper Seam ...	4.19	24.00	44.00	27.81	...	5 "
Kurasia ...	8.66	30.92	48.86	11.56	...	6 "
Kurasia, Chirmiri ...	7.77	29.1	51.2	12.0	...	10 "
Bisrampur, Rer and Pasang ...	...	37.6	57.0	5.4	...	2 "
Bisrampur, Mahan and Masan ...	...	19.6	48.0	19.6	...	3 "
Lakhanpur (Parsa) ...	7.5	28.70	50.90	12.90	...	5'6" seam
Korba (Ghordewa) ...	6.91	29.06	53.93	10.10	...	5' seam(2)
<i>Wardha Valley Coalfields—</i>						
Wun-Papur (Pisgaon) ...	...	19.4	63.9	16.7	...	2 samples
Ghugus ...	...	33.49	45.61	20.90	...	32 <sup>1</sup> "
Ballalpur ...	11.10	31.56	45.47	11.87	...	1 <sup>2</sup> "

## HYDERABAD

Of the 530,612,935 tons of coal produced in India between 1900 and 1932, Hyderabad was responsible for 19,400,531 tons, or 3.65 per cent, most of which came from the Singareni collieries. Within the Nizam's Dominions, and forming part of the Godavari-Gondwana belt, Barakar coal measures occur at numerous localities and in nearly every case they are overlaid by younger Gondwana rocks, so that their real extent is not known and can indeed only be proved by deep and extensive boring. The coalfields of Sasti and Tandur, in the Adilabad district, and of Kamaram, Madhavaram and Singareni in the Warangal district, are briefly noted below. In addition to these however, there are several other localities in both districts where rocks of Barakar age crop out which have no exposed coal seams at the surface, or where fragments of coal have been found in stream beds derived from

<sup>1</sup> Boring samples from the 32' seam.<sup>2</sup> From boring core.

exposures which still have to be found. Though of little economic interest at present, such occurrences are of great geological importance, especially with reference to future exploration by boring.

*Sasti.* The Sasti field is a continuation, on the south side of the Wardha river, of the Ballalpur field in the Chanda district of the Central Provinces, the coal occurring in two hasins between Sasti and Paoni. Part of the area was bored between 1871 and 1874 and coal with an average thickness of 40 feet proved over an area of  $1\frac{1}{2}$  square miles. Hughes calculated in 1877 that 30 million tons are available. Mining operations were carried on by the Nizam's officers from 1871 to 1874, but more systematic work was started in 1920, since when 499,338 tons have been raised, the highest output being 61,184 tons in 1932.

*Tandur.* Tandur lies about midway between Kaingura and Aknapali, and the fact that coal occurs and is visible at intervals, up to a maximum of 15 feet over seven miles, led Hughes in 1878 to believe it highly probable that it is continuous throughout this belt of Barakars which is 24 miles in length. Mining commenced about 1929, and until 1932 the output was included in that of Singareni. In that year Tandur, which has two workable seams, produced 126,471 tons.

*Kamaram.* Kamaram is a very small coalfield, 156 acres in extent, containing 1,132,560 tons of good coal, but, in the words of W. King 'ill-placed in every way for its development'.

*Madhavaram.* The Madhavaram field stretches across the Godavari below Bhadrachalam, and most of its 24 square miles lie in Hyderabad territory. It was examined by Blanford in 1871 and at that time appeared to be of no importance, but in 1891 a seam of good quality is stated to have been found near Rajahzompalli, in the Godavari district of Madras. Three seams of 1, 4 and 6 feet in thickness have been proved on the Hyderabad side of the river.

*Singareni.* The Singareni coalfield, 146 miles from Hyderabad city, was discovered and described by W. King. It occupies an elliptical area about 19 square miles in extent of which the Barakars cover 9 square miles. Four seams were proved by boring, and mining in the King seam, which averages  $5\frac{1}{2}$  feet in thickness, was commenced in 1886.



This seam alone was estimated by Saise in 1894 to contain 36 million tons, while parts of another seam, which is 30 or 40 feet thick, are also believed to be workable. In 1900 the annual output was over 460,000 tons and 10 years later it was more than half a million tons. From 1916 onwards it has been between 600,000 and 700,000 tons per annum. The total amount of coal obtained during the present century is 18,774,723 tons, and from the commencement in 1887, 21,385,695 tons, the production for 1932 being 593,466 tons, or 2.95 per cent of the Indian total. The coal itself is a dull, hard, non-coking, steam coal largely consumed by railways and mills in Southern India. The average analysis of a number of samples as loaded for dispatch shows:

Moisture	...	= 5.86 per cent	Ash	...	...	= 14.17 per cent
Fixed Carbon	...	= 55.85	Calories	...	...	= 6,433
Volatile Matter	...	= 24.12				

## CRETACEOUS, JURASSIC AND TERTIARY COALFIELDS

Although less than 2 per cent of India's coal is derived from Tertiary rocks, the coalfields of this age are of great importance to the regions in which they occur and they are mined in Assam, Baluchistan, the Punjab and Rajputana, while fields unworked at present are found in Burma, Kashmir and the North-West Frontier Province.

### ASSAM

*Garo Hills.* The westernmost coal measures of Assam, situated in the Garo hills, are of Cretaceous age and were described by H. B. Medlicott in 1874. The Daranggiri basin, with a productive area of about 20 square miles, lies across the Someswari river in the centre of the hills. The average thickness of the single workable seam is  $5\frac{1}{2}$  feet, and in 1882 La Touche estimated that it contained 76 million tons, mostly above main drainage level. The coal is of excellent quality and, according to Simpson, the only bar to exploitation is the distance from a railway. Other localities in the hills of more doubtful value include Harigaon, Pundengru, Rongrenggi and Siju.

*Khasi and Jaintia Hills.* Coals of both Cretaceous and Tertiary ages have been reported from many places in the Khasi and Jaintia hills and have been known in the Cherrapunji area since 1815. Here a seam, from 3 to 9 feet thick, covers an area of 136 acres and,

according to La Touche (1889), contains 1,185,000 tons. Mining on a small scale has probably been carried on for nearly 100 years. From another 3-foot seam of Cretaceous age covering a very restricted area at Maobelarkar, the requirements of the hill station of Shillong were met for a lengthy period. Many of the localities are quite small and, being measured in acres rather than square miles, need not be tabulated here. The Umblay River or Langrin field however, is exceptional and covers about 30 square miles. Mentioned by W. Jones in 1829, visited by Godwin-Austen in 1869, it was investigated by La Touche in 1883-84. At least four seams with an aggregate thickness of over 20 feet occur, and though no estimates have been made, it appears certain that a large quantity of coal of very fair quality exists, while some of it possesses coking properties.

In Upper Assam coal-bearing rocks occur along the lower ranges of the hills forming the southern boundary of the Lakhimpur and Sibsagar districts. The coal measures, according to P. Evans, form the Tikak Parbat and Baragolai stages, the upper and middle of the three divisions into which he divides the Barail series of Upper Assam. The former is of Oligocene age while the latter extends from the upper Eocene into the Oligocene. The coalfields themselves are structurally isolated. The carbonaceous shales which characterize these rocks further to the south-west, change into coal seams in the Dayang valley and about Cholemsen, 12 miles south-east of Mariani junction. Hence they continue to the north-east in interrupted strips to the valley of the Noa Dihing in the Sadiya frontier tract and on to the slopes of Miao Bum, in the Singpho hills beyond, a distance of over 120 miles. The coalfields to be mentioned include those of the Disai River, Janji River, Nazira (with the Dikho, Tiru and Safrai valleys), Jaipur, Namdang-Ledo or Makum, and Namchik.

*Disai River.* The extent of the Disai field is unknown but the proved length of the outcrops is about 5 miles. F. R. Mallet, in 1876, found five or six seams of crushed coal up to 4 feet thick.

*Janji.* In the Janji field which lies between the Disai and Dikho valleys, two or three thin seams have been traced for less than 3 miles. This occurrence appears to be of little importance.

*Nazira.* About 8 miles north-east of Janji, the Nazira field is situated, in which steeply inclined coal measures have been followed

for 16 miles. This area drained by the Dikho, Tiru and Safrai streams was known in 1848, examined by Mallet in 1876 and by Simpson in 1906. The Upper Safrai and adjoining tracts were investigated by Sir Henry Hayden in 1909. Mallet estimated the reserves of the Safrai area, over a length of  $4\frac{1}{2}$  miles, at an average thickness of 51 feet and within 350 feet of the outcrop, at 20 million tons, the whole of which lies below alluvium. In the Tiru-Dikho area, 18 feet of workable coal over a distance of 7 miles would yield nearly 15 million tons within 600 feet of the outcrop, much of it above ground water level. These reserves refer only to a portion of the areas concerned. Simpson calculated that in less than a mile of outcrop on the right bank of the Dikho, nearly  $2\frac{1}{2}$  million tons could be obtained from adit levels. The grade of the coal is similar to that of Makum and most of it is of a hard variety. The coal seams worked in the collieries opened at Borjan and Konjan in 1913 are, according to Evans, in the lower part of the Tikak Parbat stage. The output from that date up to the end of 1932 was 716,110 tons, the highest figure of 60,083 tons was reached in 1924, while that for 1932 was 38,403 tons.

*Jaipur.* Twenty miles north-east of Nazira lies the Jaipur field in which the coal measures have been followed for 25 miles. In the southern portion, especially near Barpatra, Disam, Hapjan and Jaipur itself, the coal seams are of considerable thickness, but north of the Dihing river, near Dhekiajuli and Saraipung, they are very much thinner. Known in 1838, the field for many years supplied the factories of the local tea gardens with fuel from outcrop quarries. Mallet, in 1876, estimated that in the 15 miles between Tipam and Boruarchali, allowing an average workable thickness of 15 feet, there was a total of 20 million tons of coal within a depth of 450 feet. In a limited area on the Disang river in which six workable seams occur, Simpson, in 1906, considered that  $1\frac{1}{2}$  million tons could be profitably extracted. Practically the whole of the coal lies below water level and its quality is somewhat inferior to that of Makum, the sulphur content in both cases being high.

*Makum.* The Namdang-Ledo, or Makum coalfield, lies to the east of Jaipur, and the coal measures occupy a narrow strip some 18 miles long and one mile broad. Mallet, in 1876, found the best

outcrops in the  $5\frac{1}{2}$  miles' stretch between the Namdang and Tirap streams. According to Evans (1932), thick coal seams with carbonaceous shales, shales and sandstones form the lower part of the Tikak Parbat stage, while the workable seams are limited to a small portion of the succession. The lowest or 'thick' coal is often termed the '60-foot seam' and in many places it is divided into three separate ones. Over this coal are two comparatively thin seams followed by the 20-foot coal, which, in its turn, is also followed by several thinner seams. In some areas, parts of the 'thick' coal are missing, and the 20-foot seam has been eroded over a large area near Baragolai. The average dip is high, but the outcrops being often some hundreds of feet above the plains, mining can be carried on from adit levels. In 1900, G. E. Harris estimated that in the stretch of ground mentioned above, there is a total quantity of 90 million tons of coal above natural drainage level. Mining commenced in 1881 when collieries were opened at Ledo, Tikak and Namdang, and a metre-gauge railway, 77 miles in length, was made to the fields from the Brahmaputra near Dibrugarh soon afterwards. The coal is of excellent quality, a valuable gas-producing material which also furnishes a hard, porous, low ash coke. Its only defect is the large amount of sulphur which it contains. In 1884 the output was 16,493 tons and by 1900 this had risen to 215,962 tons, and to 305,563 tons in 1909. Production since that time has varied between 250,000 and 300,000 tons per annum approximately, the low figure of 170,399 tons for 1932 being quite abnormal and due to the general depression. Makum coal is consumed by the railways, steamer companies and tea factories in Assam.

*Namchik.* Coal has long been known to occur in the Namchik valley to the east of the Namdang-Ledo field. According to Sir Edwin Pascoe, who examined the area in 1919, 60 feet of coal are exposed in five groups of seams, the best of which contains  $21\frac{1}{2}$  feet of coal separated by three thin clay bands. The locality is only 18 miles in a straight line from Ledo.

## ANALYSES OF ASSAMESE COALS

LOCALITY	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	NUMBER OF SAMPLES
Daranggiri (Garo Hills) ... ..	8.8	36.3	49.8	5.1	2
Jaipur ... ..	6.42	39.80	48.78	4.82	25
Nazira ... ..	5.49	39.80	50.04	6.36	12
Ledo ... ..	1.80	40.15	55.59	2.46	3 <sup>1</sup>
Tikak ... ..	2.09	37.25	58.99	1.67	5 <sup>2</sup>

The average theoretical calorific value of ten samples of Makum coal, quoted by R. R. Simpson, is 7,447 calories, compared with the value of 6,526 calories calculated for thirty-one Raniganj coals.

## BALUCHISTAN

Thin coal seams of Eocene age are known to occur in various parts of Baluchistan, but the only places in which mining is carried on are in the Bolan pass, on the Sor range, in Kalat and at Khost in the Sibi district.

*Sor Range and Mach.* C. L. Griesbach in 1880, W. T. Blanford in 1882 and R. D. Oldham in 1890, have described various exposures above Mach, in the Bolan pass, and along the flanks of the Sor range to the east of it, which have been known since 1846. For many years numerous small mines have been operated by petty contractors, mainly within 15 to 30 miles of Quetta and at Mach, in seams which nowhere exceed three feet in thickness and are usually greatly disturbed. At the commencement of the present century the aggregate production of these small mines of Mach, the Sor range and the Kalat district was 5,600 tons per annum, and with minor fluctuations it increased to over 13,000 tons in the next twenty years. The largest recorded output was in 1922 with 26,269 tons. During the period 1923 to 1932 it has varied between 12,000 and 17,700 tons and in 1932 was 13,631 tons. The total production from 1900 to 1932 was 389,370 tons. These are small figures as coal tonnages are usually reckoned, yet the deposits are not without their economic importance in a region where fuel is so scarce. The coal is of fair quality but has a high sulphur content.

<sup>1</sup> Representing an aggregate thickness of 49 feet.

<sup>2</sup> Representing an aggregate thickness of 47 feet.

*Khost.* In the hills which flank the frontier section of the Sind-Pishin railway, at a height of about 4,000 feet above sea level, thin coal seams of Eocene age have been described by Griesbach, Blanford, King, Jones and R. D. Oldham from several places. At Khost, a seam with a thickness of  $26\frac{1}{2}$  inches, was traced for about  $2\frac{1}{2}$  miles and estimated by King to contain somewhat over half a million tons of available coal. A colliery was opened here by the North-Western Railway Company. Mines were also opened at Sharigh in 1894 and at Harnai in 1910, but owing to the disturbed ground, the variations of the seams themselves and the liability of the coal to spontaneous combustion, they were later abandoned. Owing to its friability much of the Khost coal was briquetted before use. In 1900 the output was 17,664 tons per annum, rising to a maximum of 45,585 tons in 1913 and gradually falling away again to 17,085 tons in 1925. Though the colliery was closed about this time, a few thousand tons of coal continue to come every year from the neighbourhood. The total production between 1900 and 1932 was 853,329 tons.

#### ANALYSES OF BALUCHISTAN COALS

LOCALITY	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	NUMBER OF SAMPLES
Mach ... ..	10.9	33.1	41.0	15.0	...
Khost ... ..	2.28	41.51	46.52	8.84	6

#### BURMA

##### Jurassic Coals

*Panlaung Valley and Loian.* Coal seams of Jurassic age occur in the Panlaung valley, on the edge of the Southern Shan plateau, and some of the exposures were described by E. J. Jones in 1887. They were examined in 1932 by V. P. Sondhi who found the coal measures building the Legaung ridge for 8 miles and stretching in a band, 3 to  $3\frac{1}{2}$  miles wide, over the Toklet valley and through the Wetpyuye forest into the Panlaung valley proper, a distance of 13 miles. The coal is scattered in pockets, streaks and lenticles and at only one locality,  $1\frac{1}{2}$  miles south of Legaung, is it worth further examination. In the southerly extension of the measures from Myinka to Konhla, the best known locality is the Loian coalfield near Kalaw, a very disturbed

area in which the coal measures are tucked in the axes of reversed folds in older limestones or faulted down into them. Extensive underground exploration was carried on here about 1922 but without success, the seams proving exceedingly irregular, crushed and broken. Most of the Shan Jurassic coals are more or less powdery and could not be marketed without briquetting, though some of them form a good coke.

*Henzada.* The Jurassic coal seams of the Henzada district were described by Murray Stuart in 1910. Perhaps the best occurrence is near Kywezin, where a seam 8 feet in thickness is exposed, but the strata are greatly contorted and the coal crushed so that its volatile contents are low and its fixed carbon high. Attempts at mining here have not been successful, and large scale tests of the coal have been disappointing. Other seams of minor importance have been found at Hlemauk and Posugyi.

#### ANALYSES OF BURMESE JURASSIC COALS

LOCALITY	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	NUMBER OF SAMPLES
Kywezin ...	1.68	17.59	74.44	6.29	3
Loian...	0.7	26.4	60.2	12.7	3

#### Tertiary Coals

Tertiary coal seams occur in several districts of Burma. Thin, crushed and shaly seams were examined in 1896 by Sir Henry Hayden at Mithwe in Bhamo, while in the adjoining district of Katha, Noetling, in 1893, reported several, including one of fair quality, 4 to 5 feet thick, at Yuyinbyet, near Pinlebu. Near Kyaukset in Minbu, there is stated to be a seam 4 feet 7 inches thick, while from the Yaw river valley in Pakokku, Cotter and Rama Rau, in 1914, described seams varying from 5 to 6 feet in thickness but with numerous shaly partings and of low calorific power, near Letpanhla and Tazu. The irregular seam of Lime Hill near Thayetmyo and the thin ones of Cap Island, Cheduba and Ramree are probably worthless.

*Kabwet.* T. Oldham, in 1855, visited three coal outcrops a few miles west of Kabwet in the Shwebo district, and they were certainly

mined by the Burmese in pre-annexation times, i.e. before 1885. The coal-bearing area lies between the Kabwet bend of the Irrawaddy and its tributary the Man Choung. Mining was confined to a single seam about 6 feet thick. A company carried on operations here at intervals between 1891 and 1904, when the workable coal is stated to have been exhausted. The annual output varied from 10,000 to 15,000 tons, though in 1896, 23,000 tons were raised.

*Upper Chindwin.* The most extensive coalfields of Burma proper lie in an isolated part of the Upper Chindwin valley and probably for this reason remain undeveloped. The coal measures of Eocene age occupy the valleys of the Nantahin, Peluswa, Maku and Telong streams to the north of the Kale, a tributary of the Chindwin, for a distance of 55 or 60 miles. According to Noetling (1889), seams of 2 feet and under are the rule, but thicknesses up to 12 feet occur. In the Nantahin-Peluswa tract, with an area of 25 square miles, a total thickness of 48 feet of coal was considered to be available, and on the assumption that this could be worked to an inclined depth of 1,000 feet from the outcrop, there are 210 million tons of workable coal in this limited portion of the Chindwin field.

#### ANALYSES OF BURMESE TERTIARY COALS

LOCALITY	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	NUMBER OF SAMPLES
Yaw River ...	18.73	34.15	35.86	11.28	22
Kabwet (Shwebo) ...	12.27	37.45	38.97	11.31	2
Chindwin ...	10.14	34.59	49.95	5.30	13

#### KASHMIR

The coal measures of Jammu Province, Kashmir, occur on the flanks of elongated domes, strung out roughly east and west, over a distance of 40 miles across the hills some 20 miles north of Jammu city. There are six of these structures: the large Riasi dome, bisected by the Chenab river from north to south, and its isolated representative of Dandli, the smaller domes of Mahogala, Metka and Kalakot, and finally the subsidiary northern group of Dhanswal-Sawalkot found in 1924. Visited by Medlicott in 1859, various reports have been written on them including those of La Touche (1888) and



Simpson (1904). Middlemiss, in 1929, investigated in fuller detail the three smaller domes and noted briefly on the Dhanswal-Sawalkot, Chakar and Chinkah fields, the two latter forming part of the Riasi dome, west of the Chenab. Unless otherwise stated the following remarks are based on his results. The coal measures underlie the Nummulitic limestone and are divided into an upper series, probably of Eocene age and about 120 feet thick, and an irregular lower one, known also as the Bauxite series, 4 to 24 feet thick.

In the Dandli field, described by C. M. P. Wright in 1905 and by D.N.Wadia, in part, in 1928, which crosses into Poonch State, there are two or three inconstant, lenticular seams from 6 to 36 inches thick of extremely crushed coal, which according to Wright offer no inducement to exploitation. The only workable portion of the Ladda-Sanganmarg field (of the Riasi dome), in Simpson's opinion, lies between Ladda and the Anji valley, east of the Chenab, where a seam, which averages about 31 inches in thickness, probably contains about  $1\frac{3}{4}$  million tons of workable coal and possibly  $3\frac{3}{4}$  million tons above free drainage level. In the years 1902-04, 2,407 tons were won from the Ladda field. In the areas west of the Chenab, however, Middlemiss thinks that the Chakar field should produce about 9 million tons, and the region around Chinkah, 6 million tons.

The lower measures of the Kalakot field are estimated to contain about one million tons of hard coal; the upper seam of the upper measures, which is about 4 feet thick, will yield some 6 million tons of second class briquetted fuel; while the middle and lower seams, allowing  $1\frac{1}{2}$  feet for their thickness, contain a further 2 million tons of very good coal, perhaps all of which will require briquetting.

No lower measures have been found in the Metka field, but three separate seams with a total average thickness of 5 feet promise about 5 million tons of mainly friable, semi-anthracitic coal from the upper measures.

In the Mahogala field, the coals of the lower measures are valueless. Allowing a total thickness of 8 feet for the three seams of the upper measures, it is estimated that 4 million tons of soft, powdery coal 'are reasonably in sight'.

The outlying Dhanswal-Sawalkot field, which appears to be an extension of Simpson's Lodhra field, may contain 9 million tons of powdery, 'graphitic' coal. In calculating all these reserves, 1,000 feet

of depth has been taken as the limit, but there is no apparent geological reason why the seams should not extend far beyond this.

Jammu coal has an anthracitic character approaching that of the Darjeeling Himalayas in composition and probably due to the same orogenetic causes. Most of it is extremely friable with a marked foliated structure. It burns with little flame or smoke and when washed and briquetted forms a fairly good steam coal. Some varieties coke strongly and most appear to contain a high percentage of sulphur.

#### ANALYSES OF JAMMU COALS

LOCALITY	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	NUMBER OF SAMPLES <sup>1</sup>	AUTHORITY
Ladda ... ..	1.03	12.42	69.74	16.81	6	Simpson
Kalakot (Lower Measures) ...	4.70	16.36	64.31	14.63	10	Middlemiss
Kalakot (Upper Measures) ...	1.06	13.45	68.02	17.49	12	Middlemiss
Metka (Upper Measures) ...	1.96	12.60	71.54	13.90	10	Middlemiss
Mahogala ... ..	3.78	14.76	71.60	9.86	6	Simpson

#### PUNJAB

The whole of the coal seams of any economic importance in the Punjab are of the same Eocene age as those of Baluchistan, and they occur mainly in the Salt range and in the hills north of the Rawalpindi plateau.

*Jhelum.* Early accounts of the Punjab Salt range coal were published between 1848 and 1853 by A. Fleming, while a later list given by T. Oldham in 1868 mentions thirteen localities, many of which, however, have no economic significance. The coal occurs in a band of shales and sandstones underlying the scarp of Eocene limestone which caps the range, but only as lenticular beds separated by wide, barren intervals. Near the eastern end of the range at Bhaganwala, a seam up to 7 feet thick has been followed for about a mile, and in 1893, La Touche estimated 88,000 tons of available coal as proved, with possible reserves of nearly one million tons. Between 1877 and 1893 about 2,000 tons of outcrop coal were removed, and in the latter year the North-Western Railway Company commenced mining, connecting the pits with the Sind-Sagar Rail-

<sup>1</sup> Samples with over 30 per cent ash omitted.

way at Haranpur about 1896. The maximum production was 13,145 tons in 1897, and mining ceased in 1900 owing to the poor quality of the fuel.

A seam averaging not more than 2 feet in thickness occurs on the Dandot plateau where mining has been carried on for many years. In 1887, R. D. Oldham estimated the reserves at 5 million tons. Collieries were worked by the railway company at Dandot and at Pidh, 3 miles to the north-east, between 1884 and 1911, when they were sold to an Indian firm. The total output from 1900 to 1932 was 1,449,611 tons, the highest recorded annual production was 81,218 tons in 1899, and that for 1932 was 32,527 tons. The coal is a friable lignite containing a high percentage of sulphur. Amongst its other applications it is used, in a pulverized form and mixed with Bengal coal, as fuel in cement works in the Punjab.

*Mianwali.* Coal seams of both Jurassic and Eocene ages occur in the trans-Indus extension of the Salt range in the neighbourhood of Isa Khel, Mianwali district. The thin and inconstant seams of Jurassic age found at Kalabagh and Kuch have little value. A fairly continuous seam, averaging 27 inches in thickness, of Tertiary age, has been followed for about  $6\frac{1}{2}$  miles between the Barochi pass and a point west of Sultan Khel. R. R. Simpson's prediction in 1904 that mines might be established successfully has been fulfilled. The production of 765 tons in 1907, rose to over 7,000 tons in 1912. The record output was reached in 1932 with 30,792 tons and the total tonnage obtained since the commencement of operations is 249,883 tons.

*Shahpur.* The coal of the Shahpur district occurs in the same conditions as the other Tertiary varieties described. The principal places are Tejuwala, near the crest of the southern scarp of the Salt range, and Jhakarkot,  $3\frac{1}{2}$  miles farther south-west, where a variable seam averages about 3 feet in thickness. Mined on a small scale at first by small contractors, the pits are now owned by a private company, and output averages about 5,000 tons per annum. From 1905 to 1932, a total of 159,913 tons have been recorded, the best year being 1932 with a production of 9,538 tons.

# INDIA'S MINERAL WEALTH

## ANALYSES OF PUNJAB COALS

LOCALITY	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	NUMBER OF SAMPLES
Dandot ...	6.13	36.81	47.17	9.89	1
Mianwali ...	4.3	42.7	46.8	6.2	3
Shahpur (Jhakarkot) ...	7.60	35.66	46.5	10.24	1

### RAJPUTANA

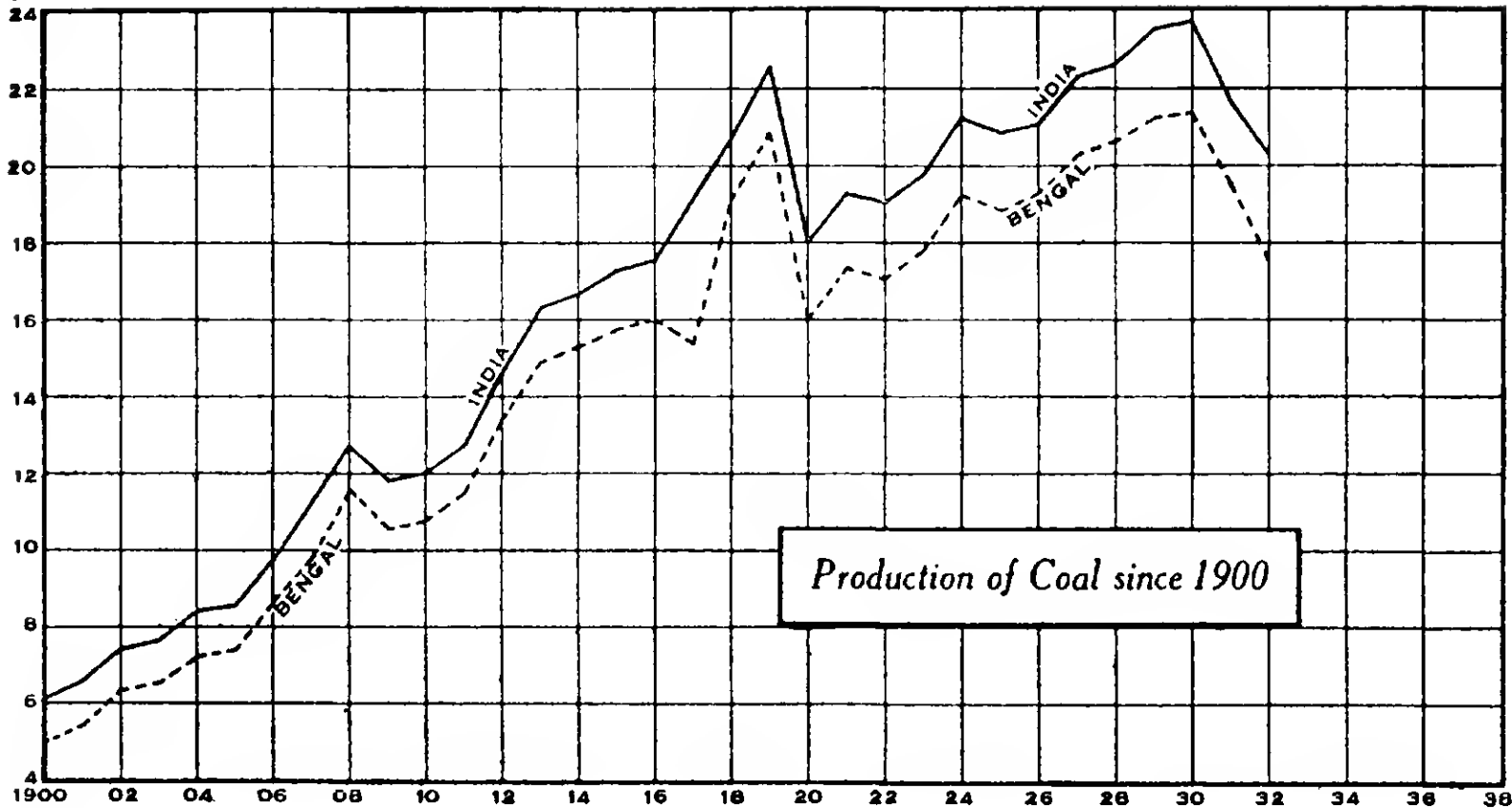
*Palana.* A seam of dark brown, woody to peaty lignite was discovered at Palana, Bikaner State, Rajputana, during well-sinking operations in 1896. It was 4 to 8 feet thick, at a depth of 212 feet from the surface and unconformably overlain by Upper Eocene limestone. It was later proved by Vredenburg to be of Laki age, which corresponds to the older portion of the Middle Eocene elsewhere and is also the age of the coal-bearing formations of Baluchistan, the Punjab and Kashmir (in part). Mining operations commenced in 1898 and proved a seam averaging from 10 to 14 feet thick over a considerable area. Railway connexion was made to the Jodhpur-Bikaner Railway and production commenced in 1900, reaching its maximum of 45,078 tons in 1904. Of late years it has fluctuated between 35,000 and 38,000 tons per annum, being 37,043 tons in 1932. The total output up to the end of that year was 722,899 tons. The coal has been used on the railway. C. S. Fox states that it frequently contains 40 to 45 per cent moisture when freshly mined, but a few days' exposure to the desert climate of Bikaner reduces it to 15 per cent and less. According to the same writer (1935), the lignite has been proved at Madh, nearly 20 miles west of Palana, at a depth of 100 feet, while another seam has been found near Chaneri 32 miles away, 180 feet below the surface. Thus the reserves may be extensive.

### ANALYSES OF BIKANER LIGNITE

	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH
Dry Lignite... ..	8.5	41.8	40.8	9.5
Briquette (1) ...	14.84	40.64	38.78	5.74
Briquette (2) ...	9.32	44.36	38.80	7.52

MILLION

TONS



*Production of Coal since 1900*

Graph 1

TABLE II

## PRODUCTION OF COAL IN INDIA, 1900-32

YEAR	TONS	VALUE AT MINES	PIT'S MOUTH AVERAGE VALUE PER TON	PROPORTION FROM GOND- WANA ROCKS	PROPORTION FROM TERT- IARY ROCKS
		£	Rs.	per cent	per cent
1900	6,118,692	1,343,081	3.29	94.6	5.4
1901	6,635,727	1,323,372	2.99	94.4	5.6
1902	7,424,480	1,366,909	2.76	95.4	4.6
1903	7,438,386	1,299,716	2.62	95.1	4.9
1904	8,216,706	1,398,826	2.9	95.02	4.98
1905	8,417,739	1,419,443	2.8	94.95	5.05
1906	9,783,250	1,912,042	2.15	95.56	4.44
1907	11,147,339	2,609,726	3.8	96.17	3.83
1908	12,769,635	3,356,209	3.15	96.90	3.10
1909	11,870,064	2,779,865	3.8	96.57	3.43
1910	12,047,413	2,455,544	3.1	96.58	3.42
1911	12,715,534	2,502,616	2.15	96.96	3.04
1912	14,706,339	3,310,365	3.6	97.23	2.77
1913	16,208,009	3,798,137	3.8	97.57	2.43
1914	16,464,263	3,907,380	3.9	97.42	2.58
1915	17,103,932	3,781,064	3.5	97.48	2.52
1916	17,254,309	3,878,564	3.6	97.74	2.26
1917	18,212,918	4,511,645	3.11	97.81	2.19
1918	20,722,493	6,017,215	4.6	98.08	1.92
1919	22,628,037	8,799,353	4.8	98.28	1.72
1920	17,962,214	9,297,853	5.3	97.58	2.42
1921	19,302,947	8,673,377	6.12	97.62	2.38
1922	19,010,986	9,755,343	7.11	97.43	2.57
1923	19,656,883	9,737,316	7.7	97.77	2.23
1924	21,174,284	10,766,433	7.1	97.75	2.25
1925	20,904,377	9,503,828	6.1	97.82	2.18
1926	20,999,167	7,574,599	4.13	98.02	1.98
1927	22,082,336	7,079,852	4.5	98.11	1.89
1928	22,542,872	6,604,106	3.15	98.27	1.73
1929	23,418,734	6,668,591	3.13-6	98.22	1.78
1930	23,803,048	6,861,134	3.14-3	98.06	1.94
1931	21,716,435	6,125,804	3.12-11	98.22	1.78
1932	20,153,387	5,120,045	3.6-1	98.32	1.68
Total	530,612,935	165,539,383			

**TABLE III**  
**AVERAGE ANNUAL IMPORTS OF COAL INTO INDIA, 1900-32, LONG TONS**  
*Arranged according to Countries of Origin*

PERIOD	UNITED KINGDOM	AUSTRALIA	UNION OF SOUTH AFRICA	PORTUGUESE EAST AFRICA	JAPAN	OTHER COUNTRIES	TOTAL
1900-01 to 1902-03	173,515	13,520	...	...	29,460	2,442	218,938
1903-04 to 1907-08	190,158	23,643	8,030 <sup>1</sup>	...	21,904	4,476	248,211
1909-13 ...	229,526	52,393	71,604 <sup>1</sup>	...	43,908	68,730	466,162
1914-18 ...	47,128	20,247	29,782 <sup>2</sup>	29,280	10,805	11,279	148,522
1919-23 ...	265,236	40,015	170,144	90,886	26,719	11,941	604,941
1924-28 ...	73,061	11,792	148,560	75,787	4,666	5,048	318,914
1929-32 ...	23,163	2,425	96,530	1,303	...	19,369 <sup>3</sup>	142,792
Total Imports ...	4,638,742	790,717	2,526,730	984,978	628,399	592,174	10,161,740
Percentages ...	45·7	7·8	24·9	9·7	6·1	5·8	...

<sup>1</sup> From Natal.

<sup>2</sup> From Natal and the Transvaal.

<sup>3</sup> Includes 14,648 tons coke.

**TABLE IV**  
**AVERAGE ANNUAL EXPORTS OF COAL FROM INDIA, LONG TONS**  
*Arranged according to Destinations*

PERIOD	UNITED KINGDOM	ADEN	CEYLON	MAURITIUS	STRAITS SETTLEMENTS	HONG KONG	JAVA	SUMATRA	PHILIPPINES & GUAM	OTHER COUNTRIES	TOTAL	VALUE
												£
1900-01 to 1902-03...	...	40,571	325,897	13,064	81,624	...	...	12,069	...	25,209 <sup>1</sup>	498,437	342,611
1903-04 to 1907-08...	...	24,077	360,427	9,550	203,724	45,356	7,936	50,461	...	15,925 <sup>2</sup>	717,456	378,536
1909-13 ...	...	8,084	466,965	2,423	187,525	...	6,120	102,239	...	41,118	814,475	498,743
1914-18 ...	...	9,422	359,496	837	88,782	...	8,496	52,141	...	20,248	539,422	328,284
1919-23 ...	...	22,954	282,951	...	74,284	...	6,685	23,496	...	34,139	444,510	515,962
1924-28 ...	10,272	13,353	260,421	984	74,956	24,308	...	4,045	14,416	45,771	448,529	428,679
1929-32 ...	17,795	...	280,095	...	35,561	141,431	...	...	38,710	21,590	537,132 <sup>3</sup>	425,724
Total Exports	122,544	511,173	10,749,372	108,167	3,533,471	914,042	146,195	1,198,124	226,920	955,801	...	...
Percentages	...	2·8	58·3	...	19·2	5·0	...	6·1	1·3	7·3 <sup>4</sup>	...	...

GRAND TOTAL, 18,465,809, valued at £13,481,753.

<sup>1</sup> Includes 17,378 tons to British East Africa and Natal.

<sup>2</sup> Includes 6,671 tons to Natal.

<sup>3</sup> Includes 1,950 tons coke.

<sup>4</sup> Includes the percentage of the United Kingdom, Java, Mauritius, British East Africa, Natal and Egypt in addition to coke shipments.



THOUSAND

TONS

1200

1150

1100

1050

1000

950

900

850

800

750

700

650

600

550

500

450

400

350

300

250

200

150

100

50

1

# *Provincial Output of Coal since 1895*

*Excluding Bengal, Bihar and Orissa*

CENTRAL PROVINCES

NIZAMS DOMINIONS

NIZAMS DOMINIONS

CENTRAL PROVINCES

ASSAM

CENTRAL INDIA

PUNJAB

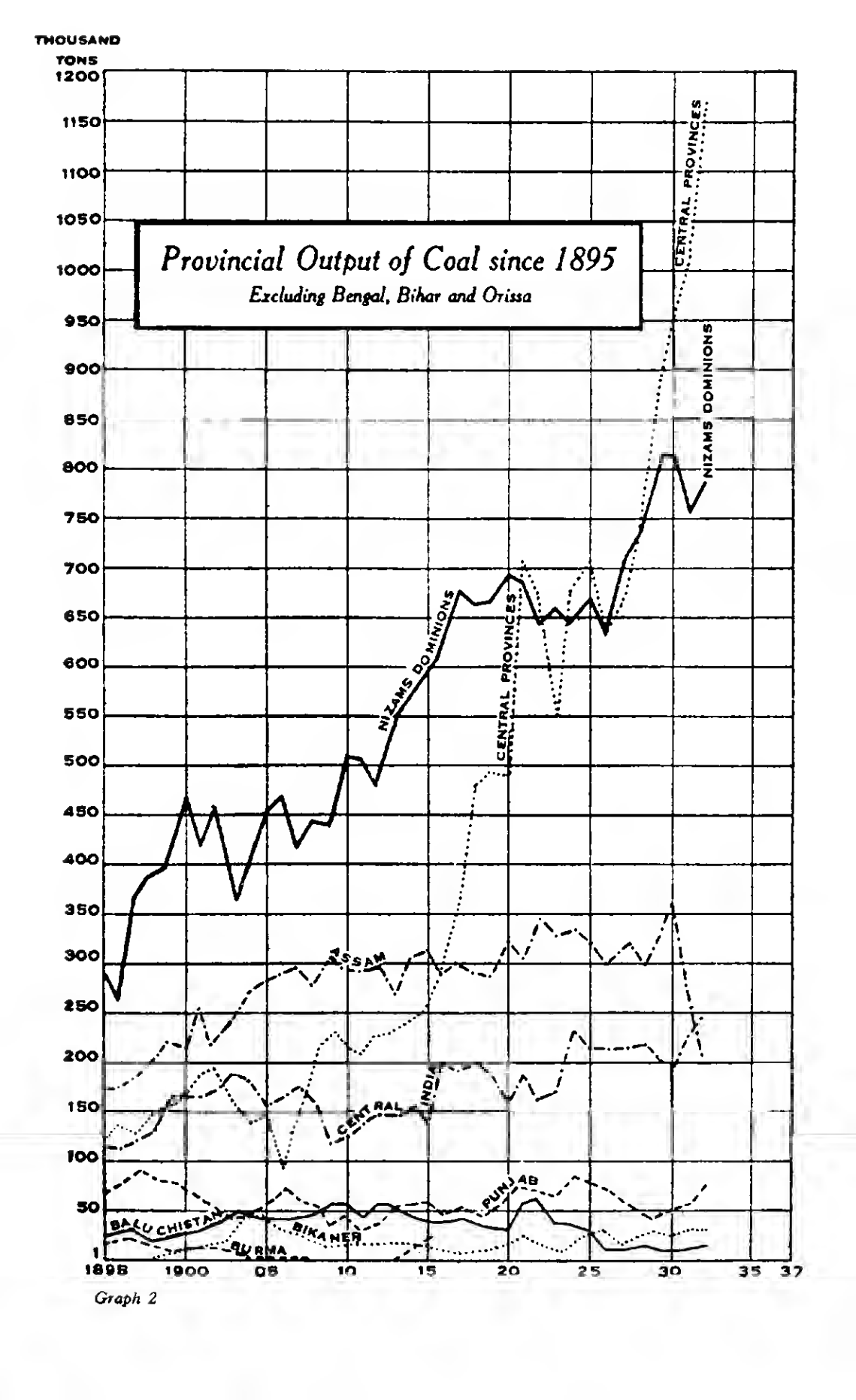
BALUCHISTAN

GUJARA

BIKANER

1898 1900 05 10 15 20 25 30 35 37

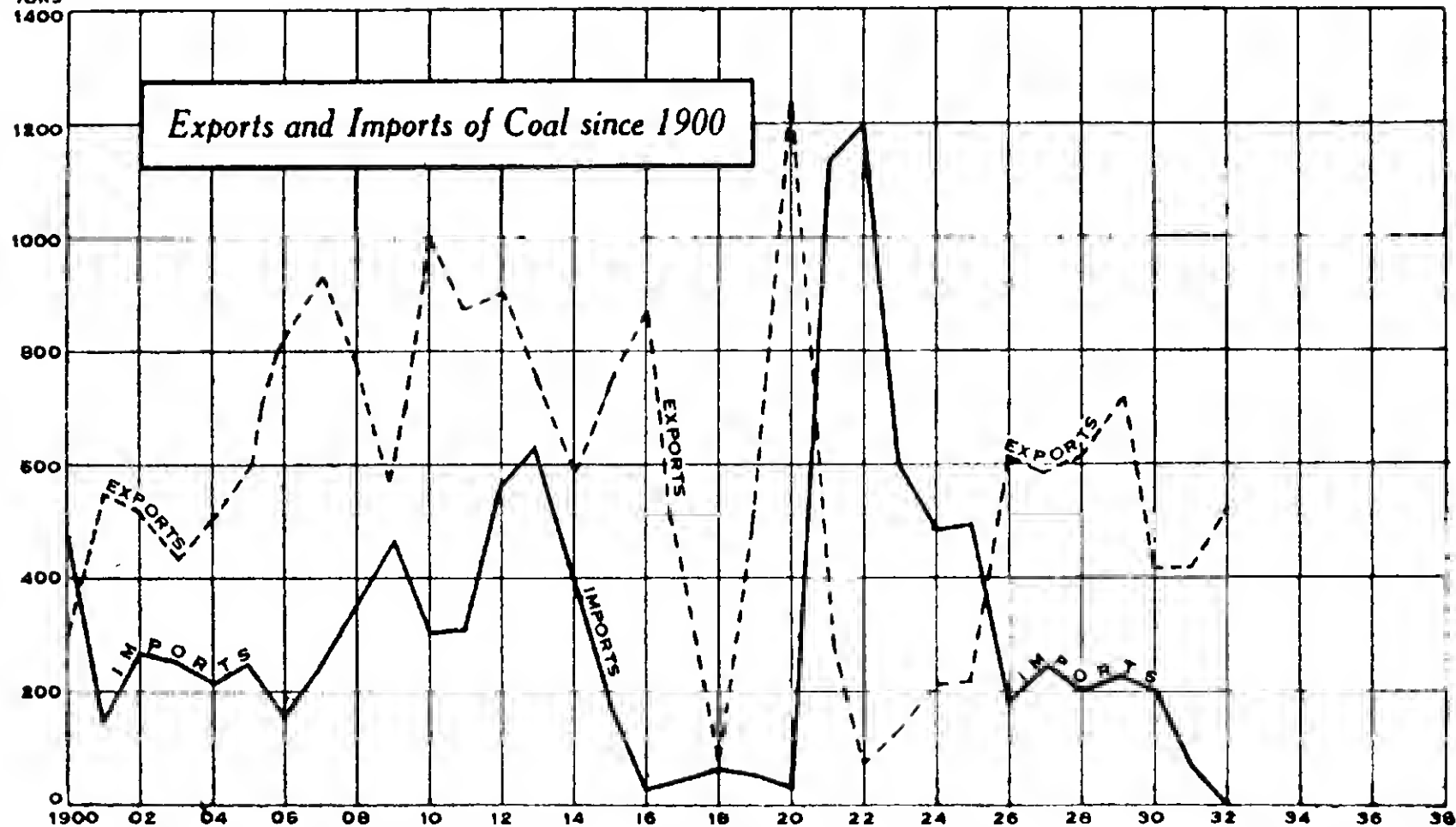
Graph 2



THOUSAND

TONS

1400



Graph 3

## LIGNITE

In addition to the lignite of Palana, Bikaner State, many Indian Tertiary 'coals' are strictly speaking lignites or 'brown coals', though their original composition is often changed as a result of the earth pressures to which they have been subjected. The term 'lignite' is used here arbitrarily to include those comparatively recent fuels of Plio-Pleistocene age, formed for the most part in areas of more or less enclosed drainage, under lacustrine or fluvio-lacustrine conditions. The examples noted are confined to Burma, Kashmir and the Federated Shan States.

## BURMA

*Theindaw-Kawmapyin.* The Theindaw-Kawmapyin coalfield of the Mergui district, Burma, in which shales, sandstones and conglomerates of late Tertiary age, deposited in old river valleys, corresponding generally with the existing courses of the important streams, are associated with seams of lignite, has been the subject of numerous reports extending over nearly 100 years. The more important of these were summarized by A. M. Heron in 1919, together with the results of his own investigations. Various seams from 4 to 15 feet in thickness are known, while the measures themselves cover an area of about 30 square miles. Practical tests of the coal are stated to have given good results, but until the field has been bored it is impossible to gauge its potentialities. Similar lignites are also known to occur in the Lenya valley in the same district.

## KASHMIR

*Shaliganga and Handwara.* The lignitic coalfields in the Karewa formation of the Kashmir valley which are of late Tertiary age, were described by C. S. Middlemiss in 1923. In the two basins of the Shaliganga area, known as Raithan and Lanyalab, a minimum of four million tons is available, while the Handwara area contains 32 million tons, in continuous seams from  $2\frac{1}{2}$  to 6 or 8 feet thick, down to easily workable levels. The areas are 40 miles apart, but if, as is probable, lignite also occurs in the higher south-western, disconnected Karewa basins, over the greater part of the valley, the quantities would become very large indeed. It is a low-grade, rather impure fuel, earthy, dark brown to black in colour and of a slabby character which can be burnt under favourable conditions in stoves and furnaces and may prove useful for distillation in the future.

## FEDERATED SHAN STATES

The lignite measures of the Northern Shan States occupy a number of distinct basins grouped around the mountain Loi Ling. They originated from peaty deposits more or less *in situ* in lacustrine and fluvio-lacustrine deposits, the formation of which is still proceeding today in the lakes which yet remain in the Shan States and adjoining countries. Thus they range in age from late Pliocene to recent times.

*Lashio.* The Lashio field, with an area of about 50 square miles, lies in the valley of the Nam Yau river, about 5 miles to the north of Lashio itself, and was surveyed by La Touche and Simpson in 1904-05. Brownish-black lignite with a distinctly woody structure has been found in several outcrops, varying from 3 to 25 feet in thickness.

*Namma.* The Namma field, with an area of 50 square miles, lies 11 miles south of the Lashio field and was investigated by Simpson in 1905. The principal seam of lustrous black lignite has been traced for about half a mile and varies from 7 to 17 feet in thickness. A portion of this field has been explored by the Burma Corporation Ltd., and two seams of average thicknesses of 12 and 21 feet proved. According to E. L. Moldenke (1922), in the small area concerned there are 50 million tons of coal in the lower seam and 30 millions in the upper one.

*Mansang and Mansele.* The Mansang and Mansele fields, 16 and 27 miles south and east of the Namma coalfield respectively, are each about  $13\frac{1}{2}$  square miles in extent. Surveyed by Simpson in 1905, they are known to contain numerous outcrops of lignite up to  $4\frac{1}{2}$  feet in thickness.

## ANALYSES OF LATE TERTIARY LIGNITES

LOCALITY	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	NUMBER OF SAMPLES
Kawmipyin (Burma) ...	13.87	35.74	43.75	6.64	2
Kashmir (General Average) ...	15	28	27	30	...
Lashio (Shan States) ...	20.65	35.63	31.08	12.64	6
Namma        "        ...	16.58	36.90	38.81	7.71	5
Mansang       "        ...	14.23	35.13	36.32	14.32	6
Mansele       "        ...	14.73	38.83	34.22	12.22	1

## PETROLEUM

## BURMA

The two oil-bearing regions of Burma are separated by the mountain ridges of the Arakan Yoma. The first includes the occurrences on the Arakan coast and is of very little importance. The second extends through the valleys of the Lower Irrawaddy and the Chindwin and includes the oilfields of Thayetmyo, Minbu, Yenangyaung, Singu, Lanywa, Yenangyat and Indaw. The oil is indigenous in Tertiary rocks of Oligocene to Miocene age, known as the Pegu system, and consisting of alternations of marine and estuarine clays, shales, sandstones and impure limestones. These rocks were deposited in a shallow sea into which a large river poured its sediments. Elevated at a later date, the Tertiary basin of Central Burma was folded into pronounced undulations, and the domes or anticlinal structures are those most favourable for the accumulation of oil, in their sandy horizons when these are sealed by impervious shales. All the producing fields lie on folds of this type in the western half of the Tertiary basin.

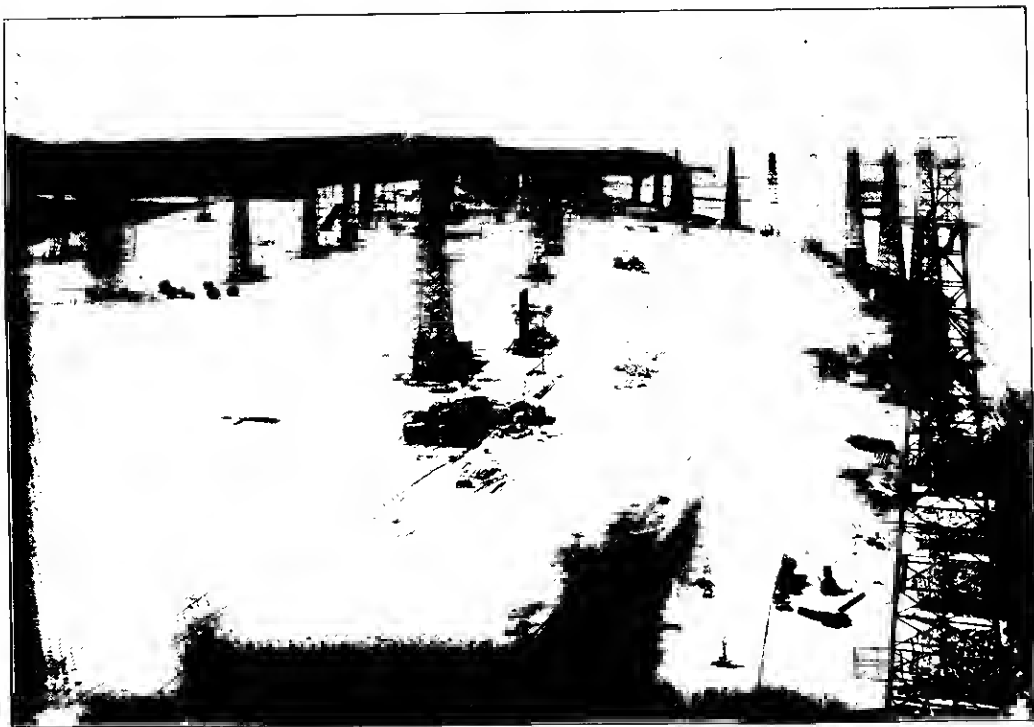
*Yenangyaung.* Yenangyaung, the richest field, lies some two miles east of the Irrawaddy, near the town of the same name in the Magwe district. It is an elongated dome of Pegu rocks, slightly asymmetrical towards the east, about six miles long and one mile broad, but the chief producing area does not cover more than two square miles.

A primitive form of oil mining has been practised here and on certain other fields for centuries by the Burmese, who sink narrow timbered shafts to sands at depths of from 200 to 400 feet and bale the oil from them. Under the Burmese monarchs the mining rights were vested in twenty-four families and their claims over two tracts of 295 and 155 acres, known as the Twingon and Beme reserves respectively, were recognized by the British Government after the annexation of Upper Burma in 1885, a specified number of sites being allotted to them annually until the whole area was so distributed. The output from this source was about  $2\frac{1}{2}$  million gallons per annum in 1888. The use of modified diving dresses by the shaft sinkers enabled them to reach greater depths and to obtain more oil, so that by 1900, production from these hand-dug wells had increased to  $8\frac{1}{2}$  million gallons. After 1908, however, a rapid decline followed as the hereditary families sold and leased their sites to

European companies. There are still about 150 of these shafts in operation, for the oil from them has its special uses and a local market.

Modern exploitation dates from 1887 when the Burmah Oil Co. Ltd. commenced drilling in Khodaung, the central area which, together with other portions of the field, is leased to it. Several other companies work within the reserves of Beme and Twingon and at the southern end of the anticline. As the dip on the western flank is rather more than it is on the east, the producing limits of the deeper oil pools extend further in that direction than was realized a few years ago, and the most prolific source of new production has been from easterly extensions of oil sands lying between 2,500 and 2,800 feet below the surface. In 1930, the discovery, at a depth of approximately 4,000 feet, of a sand in the south of the field has led to the exploration of an area at one time considered valueless. Further south still and close to the last surface exposure of the Pegu rocks, another well, 5,390 feet deep, produces from a sand at about 5,000 feet. In the central portion of the field test wells have been drilled to depths approximating 3,700 feet, without encountering as yet remunerative production below the 2,800-foot oil-bearing zone. There are over 3,000 producing oil wells on the field, some of which are operated under suction. At one time yielding over 200 million gallons of oil per annum, the decline of recent years has been persistent, the output for 1932 being 127,191,743 gallons. From the commencement of drilling in 1887 to the end of 1932, over 4,800 million gallons of oil have been taken from the Yenangyaung field alone.

*Singu.* The Singu oilfield, formerly in Myingyan but now in the Magwe district, lies further north but on the same bank of the river as Yenangyaung, and it is the southern prolongation of the asymmetric anticlinal folding which has given rise to the oilfields of Yenangyat and Lanywa on the opposite bank of the river further north still. It was first recognized by G. E. Grimes in 1897 and commenced producing oil in 1901. The greater part of the field is leased to the Burmah Oil Co. Ltd., and its output is used to make good the deficiencies of the Yenangyaung supplies. It contains rich oilsands between 1,400 and 1,450 feet below the surface and again between 1,800 and 1,900 feet, but today many wells are obtaining their supplies from the 3,000-foot sand. On the west flank a test well



*Plate III*

VIEW OF THE LANYWA OILFIELD

*Facing p. 52*

drilled to a depth of 5,860 feet, encountered oil sands at depths of 3,300, 3,700 and 4,100 feet which proved to be of minor value in this particular well but which it is considered may prove more productive on locations situated nearer the crest. There are over 500 active wells and, in addition, a large number cemented above the oil sands ready to be rapidly brought into use as occasion requires. Within the last few years an average of approximately 96 million gallons of oil has been drawn from this field annually and its total yield over the 30 years of its existence has been a little more than 2,000 million gallons.

*Lanywa.* On the north the Singu oilfield ends abruptly at the eastern bank of the Irrawaddy, which here cuts through it from north-east to south-west. There is no doubt, however, that the anticlinal crest crosses the river and that rich, oil-bearing territory lies under its bed. The crest meets the opposite bank obliquely again near the small village of Lanywa. The results of test wells having been successful on a projecting sandbank on this side of the river, the Indo-Burma Petroleum Co. Ltd., completed an embankment for its protection in 1929 and by the end of 1930 there were 17 producing wells on the field with a yield for the year of over  $17\frac{3}{4}$  million gallons. Plate III, from a photograph supplied by the courtesy of the Indo-Burma Petroleum Co. Ltd., shows the Lanywa oilfield. Today there are over 50 wells raising oil from sands between 1,700 and 2,500 feet below the surface. The embankment is being extended and the ground between it and the shore filled in and raised. Schemes are also under consideration for tapping the sands under the river bed, by means of wells from underground chambers connected to the surface by shafts and galleries.

*Yenangyat.* Continuing north from Lanywa, the same anticline forms a narrow range of hills rising steeply from the right bank of the river. The whole outcrop of Pegu rocks has a length of 39 miles and a maximum breadth of  $3\frac{1}{2}$  miles. The pitch of the fold itself and the positions of two high portions of its crest account for the oil pools of the Yenangyat field proper and for that of Sabe, a few miles further north still. In marked contrast to the western limb of the fold, the eastern one is highly inclined, sometimes vertical and even inverted. As a result of this marked asymmetry the oil pools



do not lie directly below one another, but are found at progressively greater distances to the west of the visible crest as depth increases. Although the wells here have often commenced with big initial yields, they fall off rapidly, and production from Yenangyat has never been large. Beginning with 118,400 gallons in 1893, the maximum output was reached in 1903 with  $22\frac{1}{2}$  million gallons. The inevitable decline was slow at first and more accentuated afterwards, and in 1927 only 1,844,946 gallons were won. From 1929 onwards the official returns include the figures for the Lanywa field. There are 136 producing wells in the Yenangyat and Sabe fields proper, but in the former the average initial production for a new well is now only approximately 10 barrels (400 gallons). Results obtained in deep tests in recent years seem to show prospects of the occurrence of both oil and gas below 3,000 feet in certain favourable parts of the structure. Between 1891 and 1927 (inclusive) the field yielded 211 million gallons of oil. The Yenangyat and Singu fields are connected by a pipe line and the latter in its turn is connected with Yenangyang and the refineries near Rangoon.

*Indaw.* The Indaw field lies 22 miles inland from Pantha, on the east bank of the Chindwin in the Upper Chindwin district. It is an asymmetrical, elongated dome of Pegu rocks extending over about 18 square miles, predominantly sandy in character but also containing clays and shales, especially in the lower horizons. The bulk of the present production is drawn from sands between the depths of 800 and 1,200 feet, which lie below an area of about a quarter of a square mile on the centre of the dome. The Indo-Burma Petroleum Co. Ltd., commenced drilling in 1912, but the prevalence of malaria and the difficulties of transport through the forests of this isolated region hindered progress and commercial production was not attained until 1918, the output rising to a maximum of over 2,858,000 gallons in 1930. There are now about 40 producing wells, and a deep test which reached 2,944 feet in 1931 was abandoned owing to drilling difficulties. All the test wells which have reached any considerable depth below the main oil zone have met with gas sands under high pressure, from 1,300 to 2,900 feet in depth, and the natural gas resources of the field are very large. The oil is piped to a refinery at Pantha and the finished products are distributed to various markets in Upper Burma. The total production to date is over 25 million gallons.

*Minbu.* A narrow, anticlinal fold in the Pegu rocks recalling that of Sabe-Yenangyat-Lanywa-Singu, commences some two miles north of the town of Minbu, on the west bank of the Irrawaddy to the south of Yenangyaung, and extends to the south-south-east for many miles more or less parallel to the river. Its acute folding is of a more advanced character even than that of Yenangyat, and has resulted in great compression of the beds and in the circumscribed character of the oil pools, which occur at favourable positions along the crest. Oil is won in small quantities from shallow sands between 100 and 1,000 feet below the surface just north of Minbu itself, where slight changes in the pitch of the crest are responsible for its accumulation. To the south of the town are the mud volcanoes and gas pools, situated on a fault which crosses the structure hereabouts.

*Palanyon.* Some six miles further south as the crow flies is the small Palanyon dome, where several sands in the 1,000–2,000 foot zone have yielded oil for some years. The fold here is sharply asymmetrical and the steeply dipping easterly limb is truncated by a strike fault hading to the east. A well in this locality in 1929 had an initial oil production of 125 barrels per day, accompanied by sufficient gas to satisfy the fuel requirements of the Palanyon section.

*Yethaya.* The Yethaya field lies some four miles south of the Palanyon dome on a subsidiary structure developed in the easterly synclinal limb of the main Minbu fold. In addition to shallow wells between the depths of 300 and 600 feet which have been known for many years, several oil sands lying between 900 and 1,900 feet below the surface have been exploited more recently. A deep test well which reached approximately 5,000 feet was abandoned in 1931 without obtaining oil in profitable quantities. Three miles south of Yethaya small quantities of oil are won from shallow wells at Petpe, which lies on the main Minbu structure.

Much of the oil from the Minbu field is of a heavy type and less remunerative to refine than that from other fields in Burma, though this does not apply to that drawn from the deeper portion of the Palanyon structure. Taking the field as a single unit there are over 340 producing wells in operation. Output was first recorded in 1910 and reached a maximum of over 6 million gallons in 1928, falling to about 4 million gallons per annum at the present time. A grand

total of over 83 million gallons has been drawn from the various sections of this anticline.

*Padaukpin.* The small oilfield of Padaukpin lies 8 miles north-north-west of Thayetmyo on the west bank of the Irrawaddy, south of Minhu, and is situated on a broad, anticlinal fold of Pegu rocks developed in the trough of a wide local syncline. Small amounts of oil were obtained here from hand-dug wells in the times of the Burmese kings. Early efforts at modern drilling, about the beginning of the present century, yielded only negligible results, but in 1920, further tests by Indo-Burma Oilfields (1920) Ltd., led to an initial production of over 91,000 gallons. Eighteen wells have been drilled to depths ranging from a few hundred to 2,800 feet.

*Yenanma.* Official statistics do not separate the production of the Padaukpin field from that of Yananma, which lies 35 miles north-west of Thayetmyo. Three shallow wells were drilled here without much success some years ago, and as no clearly defined anticlinal structure has been recognized, the occurrence of the oil here has been the subject of controversy. Since 1920 some 70 wells have been drilled to depths of about 900 feet by the Company mentioned in the preceding paragraph. The total recorded production of oil from the Thayetmyo district is about  $12\frac{3}{4}$  million gallons. During better years it has averaged approximately 1,100,000 gallons per annum; today it is about half that amount.

*The Arakan Islands.* The islands off the Arakan coast, long noted for their mud volcanoes and the submarine eruptions in the neighbouring sea, contain oil deposits of doubtful value, and hand-dug wells have been in existence on some of them for an unknown length of time. At the beginning of the present century the outputs of the Akyab and Kyaukpyu districts were roughly 50,000 and 100,000 gallons per annum, respectively. The Akyab production slowly dwindled and finally ceased in 1930, while Kyaukpyu still languishes at about 13,000 gallons annually. In thirty-two years the combined areas have given a total of 1,894,000 gallons, or less than the Yenangaung field alone still produces in one week. Special rules exist for the grant of petty oil leases in the Kyaukpyu district, which are limited in area to a maximum of one acre and in time to ten years.

The Akyab oil came from the Baronga Islands, of which there are three, just south of Akyab. Gas vents and oil seepages occur on all of them though most of the oil was obtained from hand-dug wells, about 300 feet deep, in the southern end of the eastern island. The local rocks are sandstones and shales, probably of Oligocene or Miocene age in steep, overfolded, narrow anticlines.

In the case of the Kyaukpyu oil there are two small producing areas on Ramri Island, near Minbyin in the northern and at Ledaung in the southern section, respectively. They first came to the attention of Europeans about a century ago. Several wells were drilled at Yenandaung, on the Minbyin area, by the Canadian system, and although encouraging initial yields were obtained, they gradually diminished and the industry passed into local hands. The productive wells, usually 250 to 300 feet deep, though sometimes reaching 500 feet, are laid along two parallel bands about 300 yards apart, perhaps representing an oil sand in the two limbs of a sharply folded and denuded anticline, as the whole region appears to have been crushed into steep, narrow and contiguous folds. At Ledaung, there are two similar bands from which oil has been obtained by means of a few shallow, hand-dug wells. In the opinion of Sir Edwin Pascoe, folding and denudation have been too severe in these regions to warrant the expectation of oil in large quantities.

In addition to the main fields thus briefly described, petroleum is known to occur at many other places in Burma, and descriptions of them are to be found in Sir Edwin Pascoe's memoir. (See Map IV.) In the compilation of these notes the author has had the great advantage of the help of Mr C. T. Barber, lately Resident Government Geologist of the Burma Oil Fields, and the benefit of the friendly criticism of Messrs T. Dewhurst, G. W. Lepper and P. Evans of the Burmah Oil Co. Ltd.

#### ASSAM

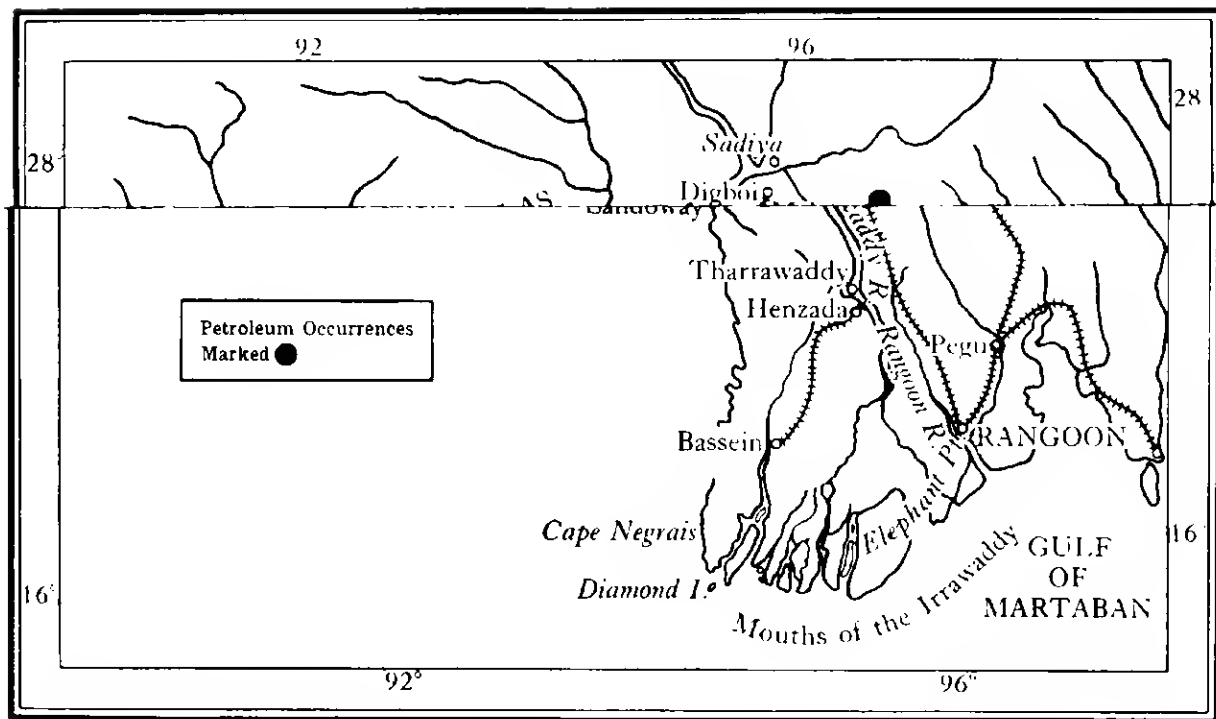
A belt of rocks in which oil and gas occurrences have been found stretches along the eastern borders of the Brahmaputra and Surma valleys from the extreme north-east of Assam, through Eastern Bengal to the islands off the Arakan Coast, a distance of about 800 miles. It is roughly parallel to the oil belt of Central Burma, but on the opposite side of the Arakan Yoma and its mountain extensions to the north. The rocks are a portion of the Tertiary system, including

representatives of the Eocene, Oligocene, Miocene and probably Pliocene, and are often compressed into more or less overfolded anticlines, the lower beds being exposed in long, narrow strips through the removal of the younger strata above them. Much activity has been displayed in the search for these structures and in the exploration of suitable ones by the drill, but the only areas which have yielded oil in commercial quantities are those of Digboi in the Lakhimpur district of Upper Assam and Badarpur in the Surma valley, although small quantities of oil have been found in the Makum-Namdang area of the Lakhimpur district and at Masimpur and Patharia in the Surma valley.

*Digboi.* The Digboi field, about 7 miles north of Margherita, was first bored in 1888, but it was not until 1892 that production was recorded. In 1921 the Burmah Oil Co. Ltd., took over the technical management of the Assam Oil Co. Ltd., and this has led to a steady expansion of the production, which reached 54,198,185 gallons in 1932. Extension drilling in the south-west was disappointing, but extension wells to the east in Hansapung were completed with satisfactory results in 1930 and 1931. The field has now been proved for a length of  $2\frac{1}{2}$  miles and includes the Digboi, Bappapung and Hansapung areas, all of which lie on an asymmetric anticline with a steeply faulted northern flank. A deep test in 1931 crossed the overthrust fault on the northern flank of the fold. The total recorded production is over 374,000,000 gallons. The crude oil is distilled in a refinery close to the field which has recently (1934) been provided with efficient and flexible plant to meet the increasingly exacting demands for improved products, and to permit of changes in manufacture to take advantage of fluctuating market conditions. Adequate supplies of crude oil for this plant are now assured from the Digboi field for many years to come.

The oil occurrences of Upper Assam are commonly found in close association with the coal-bearing rocks of the same region, and according to G. W. Lepper, 'there is no separation of "oil measures" and "coal measures" for, although most of the oil-shows are well below the thickest of the coal seams, oil sands often occur in between the thinner seams, and petroliferous coal seams have been recorded'.

*Badarpur.* The seepages which occur near Badarpur in the Cachar district led to drilling by the Badarpur Tea Co., and the



*India's Mineral Wealth*, facing p. 58

Scale, 1 inch = 114 miles

#### Map IV

#### OCCURRENCES OF PETROLEUM IN ASSAM AND BURMA

Taken with permission from *Quinquennial Review of Mineral Production of India*, and certain additions made

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*Digboi.* The Digboi field, about 7 miles north of Margherita, was first bored in 1888, but it was not until 1892 that production was recorded. In 1921 the Burmah Oil Co. Ltd., took over the technical management of the Assam Oil Co. Ltd., and this has led to a steady expansion of the production, which reached 54,198,185 gallons in 1932. Extension drilling in the south-west was disappointing, but extension wells to the east in Hansapung were completed with satisfactory results in 1930 and 1931. The field has now been proved for a length of  $2\frac{1}{2}$  miles and includes the Digboi, Bappapung and Hansapung areas, all of which lie on a synclinal anticline with a steeply faulted northern flank. A deep test in 1931 crossed the overthrust fault on the northern flank of the fold. The total recorded production is over 374,000,000 gallons. The crude oil is distilled in a refinery close to the field which has recently (1934) been provided with efficient and flexible plant to meet the increasingly exacting demands for improved products, and to permit of changes in manufacture to take advantage of fluctuating market conditions. Adequate supplies of crude oil for this plant are now assured from the Digboi field for many years to come.

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*Badarpur.* The seepages which occur near Badarpur in the Cachar district led to drilling by the Badarpur Tea Co., and the





registration of the Badarpur Oil Syndicate in 1912. In 1915 it was announced that an agreement had been made with the Burmah Oil Co. Ltd. As described by G. W. Lepper, it is a small dome with a steep, faulted, eastern flank, about a mile long with a maximum width of a quarter of a mile. Output commenced in 1917, reached a maximum of over 8 million gallons in 1920, rapidly dropped to half that amount and has since gradually decreased to 847,217 gallons in 1932. The total yield exceeds 58 million gallons (1932). The oil is of poor quality and is accompanied by large quantities of water. About 60 wells have been drilled, but the decline in yield has been abnormally rapid both from shallow and deeper sands and, as production statistics show, the additional yield of oil from new drilling and reconditioning has for some time been insufficient to offset the natural decline. The field was abandoned in 1933.

*Masimpur.* Ten miles to the east of Badarpur lies the Masimpur anticline, a large closed structure with many gas and oil seepages. A small initial production from an experimental well was recorded in 1927, and by the end of 1928 four wells had been drilled, but all had experienced trouble from water. Work was temporarily suspended in 1930 and a new test was commenced in August 1931. The production from 1927 to 1930 was 57,145 gallons.

*Patharia.* The Patharia hills anticline to the south-west of Badarpur lies on the south-eastern edge of a wide alluvial area in the Surma valley, and according to G. W. Lepper is an asymmetrical fold with a steeply faulted western flank. It, too, is being prospected by drilling, the yield from the test wells for the years 1930-32 being 246,599 gallons.

#### PUNJAB

Corresponding to the folded system of Tertiary rocks on the east of the Indian Empire in Assam and Burma, and its extension to the south into the oilfields of Sumatra, Java and Borneo, there is a similar system on the west in the Punjab, the North-West Frontier Province, Baluchistan and Sind, with a continuation beyond into the oilfields of Persia and Iraq. Oil seepages have been found in the Attock, Mianwali, Rawalpindi and Shahpur districts of the Punjab; in the Kohat district and the Shirani hills of the North-West Frontier Province and at various places in Baluchistan. As in Burma and

Assam, the oil was accumulated in a shallowing arm of the sea, though this happened at a somewhat earlier stage of the Tertiary period in the west. 'In many parts of the Punjab, however,' writes Sir Edwin Pascoe, 'and in the Baluchistan area the rock folds have been too deeply truncated by agents of denudation, or have been dislocated by earth movements, and much of the original stores of oil have disappeared; oil seepages are common enough, but most of them appear to be mere "shows", not connected with reservoirs that can be tapped by artificial means.'

*Khaur.* Khaur, the only producing oilfield of the Punjab, lies on the Potwar plateau, 43 miles south-west by west of Rawalpindi. Structurally it is a long, very slightly asymmetrical, open, anticlinal fold, a bout 7 miles long and  $1\frac{1}{2}$  miles across at its widest point, with a rounded crest and a normal pitch. Its recognition as an oilfield is due to E. S. Pinfold of the Indo-Burma Petroleum Co. Ltd. Drilling was commenced by the Attock Oil Co. Ltd. in 1915, but until 1922, when a refinery was completed at Rawalpindi, production was small. Since then it has fluctuated between nearly 6 million gallons, and a maximum of over 19 millions in 1929. In the following year there was a drop to 7,662,000 gallons, while for 1932 the figure was 5,900,480 gallons. The total production from the field has been about 113 million gallons (1932). The oil occurs in sandstones of Murree age, but is believed to have migrated upwards from underlying limestones.

Numerous productive oilsands occur from a depth of 400 feet downwards to the 4,600 to 4,800-foot oil-bearing zone. The oil is erratic in its distribution and although large yields were obtained from the 3,100 and 3,300-foot sands, and again from a deeper sand at 3,800 feet, it has been stated that the production from the 4,600 to 4,800-foot zone is insufficient to justify its intensive development. Systematic exploration of the proved sands during 1933 gave some new supplies of oil, but not in sufficient quantity to counterbalance the natural decline of the older wells. A deep test has recently been carried down into the underlying limestones and small amounts of oil found between 5,687 and 5,877 feet, where water under high pressure was struck and prevented further progress for the time being. In June 1934, it was announced that further wells are to be deepened to test the gas and oil shows which are known to exist between 5,478 and 5,620 feet.

*Dhulian.* The Dhulian dome lies about 8 miles west-south-west of Khaur and is of about the same length as the former anticline, though somewhat broader and flatter. Four test wells have been drilled on it without success in the past. A new site has lately been selected (1934) and drilling is to be resumed at an early date.

*Chharat.* The Attock Oil Co. Ltd. drilled a test well on the Chharat anticline, which also lies within the Attock district and where several oil seepages occur, during 1934, but it was abandoned later.

Indian petroleum production, as the figures in Table V prove, has increased from an annual average of about 58 million gallons, worth less than a quarter of a million pounds sterling, at the beginning of the century to nearly 308 million gallons, valued at almost  $4\frac{1}{2}$  million pounds per annum at present. The highest output was reached in 1930 with a production of 311,030,108 gallons, or approximately 1,224,000 tons, and as the world's total for that year was almost 194 million tons of oil, it is evident that from this point of view the Indian fields are insignificant: of late years the Indian output has consistently represented much below one per cent of the world's total. To India, however, the oilfields are of great importance and by far the greater proportion of the oil has been contributed by the Burmese fields, though the provincial share has dropped from 98 to 81.4 per cent over the period here reviewed, while the contributions of Assam and the Punjab have risen from 2.4 and 0.0 to 15.5 and 3.1 per cent respectively.

The consumption of oil in many forms is rapidly increasing in India and deficiencies in the home supplies have to be met by the importation of foreign oils, which in the five years ending 1933 totalled over 228 million gallons per annum, worth over £7,000,000. The chief sources are Persia and the United States of America, though Borneo and Russia also contribute substantially to the total, which for the five years ending 1933 was made up of the following products: kerosene, 39.9 per cent; fuel oil, 46.0 per cent; batching oil, 5.5 per cent; lubricating oils, 4.5 per cent; petrol and similar highly volatile hydrocarbons, 2.7 per cent and other kinds 1.4 per cent.

Indian oil exports have dwindled of recent years to comparatively small volumes, consisting mainly of heavy oils shipped to the Straits Settlements and Ceylon. The exports of paraffin wax, however, are a

most important article of commerce, and for the five years ending 1933 averaged 54,600 tons annually, valued at over 2½ crores of rupees. Indian paraffin wax has a very wide distribution and is sent to most parts of the British Empire, to many countries in Europe and America as well as to China and Japan. Strangely enough India also imports this substance, the average annual quantity for the five years ending 1932-33 being 906 tons, valued at Rs. 4,48,171, derived almost exclusively from the United States of America.

**TABLE V**  
**AVERAGE ANNUAL PRODUCTION OF PETROLEUM**  
**IN INDIA, 1900-33**

PERIOD	AVERAGE ANNUAL PRODUCTION	AVERAGE ANNUAL VALUE	PROPORTION YIELDED BY		
			Burma	Assam	Punjab
	<i>Gallons</i>	<i>£</i>	<i>%</i>	<i>%</i>	<i>%</i>
1900-03 ...	58,067,771	231,319 <sup>1</sup>	97·6	2·4	...
1904-08 ...	146,506,989	592,887 <sup>1</sup>	98·0	2·0	...
1909-13 ...	240,187,714	928,072 <sup>1</sup>	98·2	1·8	...
1914-18 ...	282,594,121	1,134,916 <sup>1</sup>	97·4	2·5	0·1
1919-23 ...	299,453,675	7,036,298	95·0	3·7	1·3
1924-28 ...	290,321,036	6,268,229	88·9	7·7	3·4
1929-32 ...	307,700,745	4,222,114	81·4	15·5	3·1

**TABLE VI**  
**AVERAGE ANNUAL IMPORTS OF MINERAL OILS**  
**INTO INDIA, 1900-33**

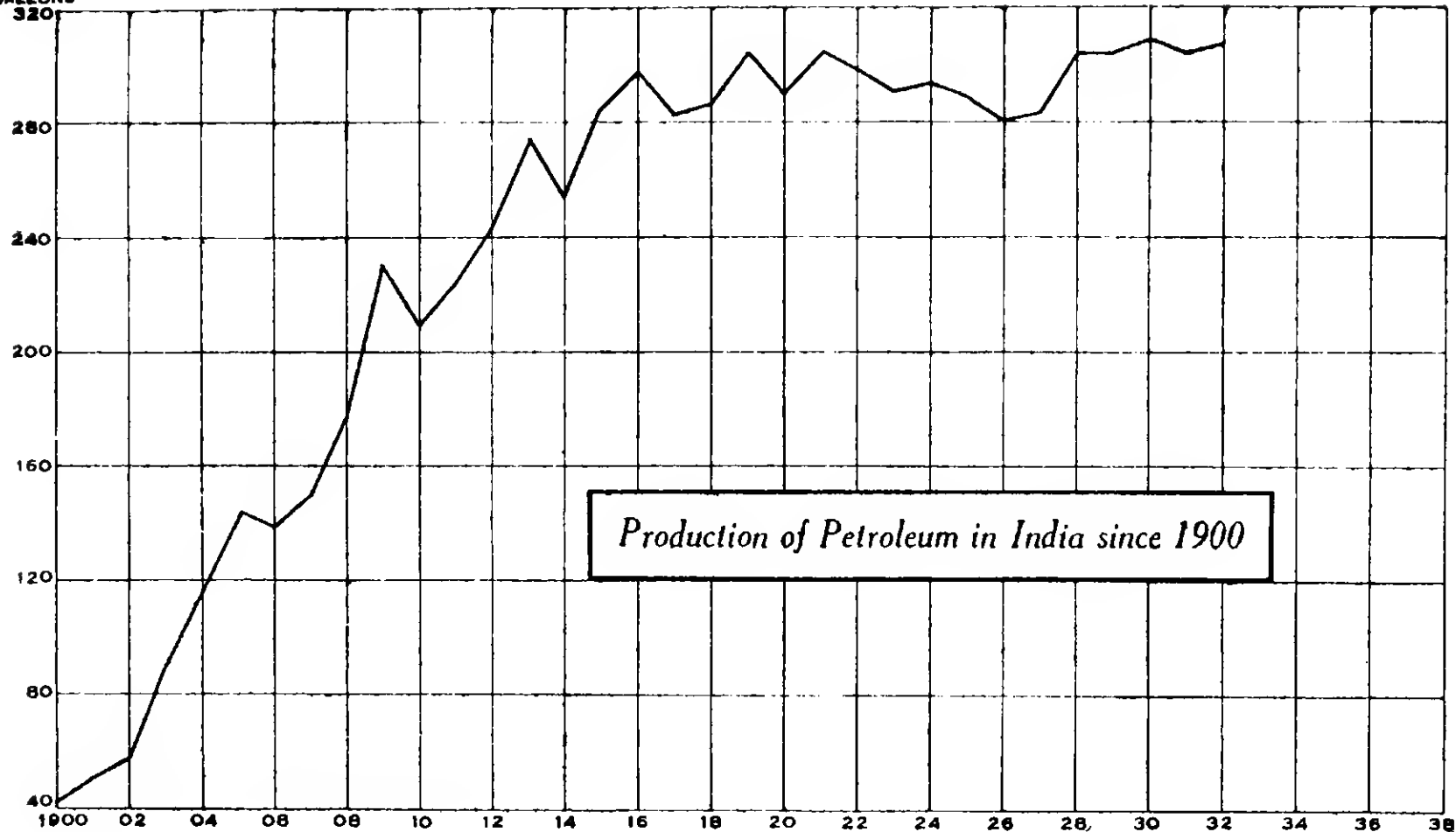
PERIOD	AVERAGE ANNUAL IMPORTS	AVERAGE ANNUAL VALUE	PROPORTION BOUGHT FROM				
			Russia	U.S.A.	Borneo	Persia	Others
	<i>Gallons</i>	<i>£</i>	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>
1900-03 ...	85,463,994	2,314,801	74·6	18·9	...	...	6·5
1904-08 ...	73,624,177	1,944,175	31·6	32·5	...	...	35·7
1909-12 ...	89,329,698	2,451,987	7·2	53·2	18·0	0·27	21·31
1914-18 ...	89,747,579	2,748,990	0·4	54·8	23·3	9·2	12·3
1919-23 ...	117,241,203	5,514,977	...	40·0	19·2	32·4	8·4
1924-28 ...	194,518,757	6,999,856	...	34·8	17·0	38·2	10·0
1929-33 <sup>2</sup> ...	228,315,287	7,194,427	13·6	17·2	13·7	42·7	12·8

<sup>1</sup> Value stated officially to be greatly under-estimated.

<sup>2</sup> Fiscal years. Percentages are for four years only, 1928-29 to 1931-32.

The record year for oil production in India was 1930, when the output reached 311,030,108 gallons.

MILLION  
GALLONS



*Production of Petroleum in India since 1900*

Graph 4

**TABLE VII**  
**AVERAGE ANNUAL EXPORTS OF INDIAN**  
**PETROLEUM AND PARAFFIN WAX**

PERIOD	PETROLEUM	PARAFFIN WAX
	<i>Gallons</i>	<i>Tons</i>
1904-08 ...	2,921,400	3,276
1909-13 ...	12,070,369	11,555
1914-18 ...	24,458,917	21,191
1919-23 ...	23,732,622	26,595
1924-28 ...	7,568,961	39,779
1929-33 <sup>1</sup> ...	123,972	54,600

### OIL SHALE

The oil shales of the Kawkareik township, in the Amherst district of Burma, lie to the east of the Dawna Range and close to the Siamese frontier, indeed two of the three basins in which they occur actually cross the frontier and are partly in Siam. Originally noticed by a passing hunter who found the local Karen tribes using the shale for fuel, the deposits were described by Professor J. W. Gregory in 1923 and by G. de P. Cotter in 1924. Two areas bisected by the Thaungyin river and lying to the south and north of the frontier town of Myawaddy, are known as the Phalu and Mesauk-Methalaun-Melamat basins respectively, though it is possible that they join and form a continuous area in Siamese territory. The third is in the valley of the Mepale stream and derives its name from the village of Htichara. The basins themselves are hollows in the older rocks which have been filled in by fresh water deposits of late Tertiary age, for the shales contain fish remains, snail shells and the leaves of plants and ferns. They fall into two divisions, a lower group of sands and boulder beds and an upper one of shales with oil shale. In the Htichara basin, which is about 14 miles long and 9 miles broad, several quite rich seams of oil shale of varying thickness have been proved by boring to exist over a considerable area and down to a depth of 300 feet. The 'Mark Band' seam is 6 to 7 feet thick and is stated to yield 15 to 20 per cent of crude oil. Five other seams with smaller oil percentages have been located above it. A sample of the crude oil obtained from the shale by distillation and analysed by the Geological Survey of India contained: water, 13 per cent; light

<sup>1</sup> Fiscal years.

naptha, 4 per cent; heavy naptha, 3 per cent; kerosene, 23 per cent; lubricating oil, 40 per cent; residue, 17 per cent. 'In the Htichara field,' states Cotter, 'there appears to be a good supply of shale of a rich or fair average quality, so much in fact that it would be possible to obtain large quantities by open-casting. Mining again is fairly simple; the strata dip gently, they appear to be fairly regular, the barren shales can form an excellent roof and floor, while the shales themselves would form good, hard pillars.' Originally bored by M. E. Moola & Sons Ltd., the Htichara deposits are now leased by the Mepale (Burma) Oil Co. Ltd., and an experimental retort for distillation was obtained in 1932.

Oil shales have also been found among the Tertiary deposits which occupy the valley of the Theinkun stream, a branch of the Little Tenasserim river, in the Mergui district, Burma, while other low grade material is known to occur near Bonkun, in the Lenya valley of Mergui, and in that of the Great Tenasserim in the adjoining Tavoy district.

Low grade oil shales have also been noted by Cotter in association with the salt marl of the Punjab Salt range, but they are not believed to possess any economic importance.

## NATURAL GAS

Great quantities of natural gas, consisting chiefly of methane, with smaller amounts of other hydrocarbons, occur associated with petroleum in various oilfields of the Indian Empire, and until comparatively recent times vast volumes of it were wasted. It is now realized that the pressure under which oil and gas exist in a sand, together with the amount of gas actually dissolved in the oil itself, are very potent factors in the recovery of the oil, for it is the propulsive power of the gas which carries the oil to the well and helps to raise it there. Modern oil technology therefore permits as little gas as possible to escape and aims at keeping the gas-oil ratio as low as circumstances permit. Gases flowing or pumped from oil-sands are also saturated with the vapours of highly volatile liquid hydrocarbons in suspension and these form a valuable source of 'gasoline', when recovered in suitable plant. Thus in 1931, over two million gallons of natural gasoline were extracted from gases liberated on the Yenangyaung oilfield alone, where there are two absorption plants at work. Others are in operation at Singu and Lanywa. The

dry gas, stripped of its liquid content, is used for fuel purposes and produces the electrical power which supplies the major oilfields with energy. Any surplus which remains is returned to the underground reservoirs whence it came, to perform more useful work in re-pressuring the depleted sands and in bringing another load of gasoline to the surface.

In addition to the gases in association with oil there are other sands in various fields which contain gas alone. This is usually methane in the dry condition. The natural gas resources of Burma have been investigated recently by Mr C. T. Barber and will be described in his forthcoming memoir. Two cases only can be mentioned here to indicate generally how large these resources are. On the Indaw oilfield alone there is an available production of some 12 million cubic feet per day which could doubtless be increased if necessary. Several oil wells have been abandoned there on account of high gas pressure. Well No. 1 has been delivering gas steadily for 15 years with very slight decline in yield and pressure and will probably continue to do so for years to come. At the other end of Burma in the Thayetmyo district, a well searching for oil liberated gas at a depth of 2,525 feet, in quantities estimated at 39 million cubic feet in 24 hours. After 8 months the well was brought under control with only a slight diminution of pressure. The liberated gas in this case was the thermal equivalent of an oil well producing 5,000 barrels per day. Recent research has shown wide possibilities in the chemical utilization of methane and its associated gaseous hydrocarbons, as a basic raw material for the synthesis of organic chemicals—dyestuffs, solvents and anæsthetics. These natural gases are in some countries piped for great distances to industrial centres for heating, domestic and power purposes; in the United States of America they are further exploited as a source of helium, the non-inflammable gas used for filling airships. An investigation is in progress at present into the helium contents of Burmese natural gases.

Sir Edwin Pascoe has pointed out a curious coincidence between the two oil belts of Assam and Punjab-Baluchistan. They are both characterized by areas which, so far as our knowledge goes, are exclusively gas areas, one at the extreme head and the other near the mouth of the Tertiary gulfs in which the rocks were deposited. In the Assam gulf the areas are respectively those of Namchik and Chittagong; in



the Punjab-Baluchistan belt they are respectively Jawalamukhi and the area of Las Bela and the Southern Makran.

Natural gas has been tapped at Jagatia and Gogha in Kathiawar and at Baroda and is believed to be derived from Upper Tertiary strata which rest on a platform of Deccan trap and thicken towards the Gulf of Cambay. P. K. Ghose (1934) states that the Gogha gas sand is 35 feet thick and occurs at a depth of 812 feet below the surface; but although the structure of the Tertiary belt of north-east Kathiawar may appear favourable for the presence of concealed gas fields, further exploratory drilling is essential before any useful conclusions can be drawn.

Natural gas in much smaller quantities is sometimes met with in sinking tube wells for water in alluvial districts, and such occurrences have been reported recently from Saharmul, Mymensingh District, Eastern Bengal, and from Thetkala, Pegu District, Burma. In these and similar cases the marsh gas was probably formed by the decomposition of vegetable matter in the local deltaic deposits.

PART II

THE METALS AND THEIR ORES

## CHAPTER II

### THE PRECIOUS METALS: GOLD, SILVER AND PLATINUM

#### GOLD

PLINY, in A.D. 77, referred to the country of the Nareæ, now identified with the Nairs of Malabar, as containing many mines of gold and silver, and there is little doubt that gold mining in India dates from prehistoric times. Owing to the absence of references in the medieval Mohammedan records, however, some authorities believe that the greatest activity took place before A.D. 1000. The occurrence of alluvial gold in the southern portion of the Malabar district has received attention from the year 1793 onwards, and in 1831 Nicholson discovered the remains of numerous old workings in the south-east Wynaad, the highlands which lie between the Nilgiri plateau and the low country of Malabar proper. The region was prospected from about 1875 onwards but, although occasional discoveries of very rich pockets were made, the results on the whole were very poor. In spite of this no fewer than 33 companies were floated between 1879 and 1881, with an aggregate capital of over £4,000,000. The total quantity of gold produced appears to have been about 600 oz. and mining operations ceased in 1893. Investigations by Sir Henry Hayden and Dr F. H. Hatch, in 1899, of the veins near Devala and Pandalur gave average gold contents of under 2 dwt. to the ton.

The gold of Southern India and of Chota Nagpur is derived from quartz veins which traverse the rocks of the Dharwar system, consisting mainly of hornblende and chlorite schists, epidiorites, greenstones, phyllites and rare mica schists, together with bands of conglomerate and quartzites. They are found in long, isolated, parallel bands and outlying patches in the gneisses, granites and charnockites which form the main mass of the Archæan complex. The vein quartz occurs in **two forms**, either as a blue, or deep grey, semi-translucent variety, bearing the marks of the intense stresses to which it has been subjected, and usually associated with the hornblende schists—metamorphosed

igneous rocks; or an opaque, milky white kind connected with the intrusion of the basic dykes, chiefly dolerites, which are common in the system and of later age. While both varieties may be auriferous, the former kind more often carries gold in the south, while the reverse is the more general rule farther north. In the case of the Kolar goldfield, now to be briefly described, some geologists trace a connexion between the auriferous vein and the hornblende schists, while others attribute the metal to the invasion of the Dharwars by the Champion gneissic granite.

The Kolar goldfield is in the district of the same name in eastern Mysore, about 125 miles west of Madras, and lies on a plateau 2,800 feet above the sea. Warren, in 1802, first directed attention to it after seeing shallow mining in eluvial deposits from which fragmentary quartz was extracted, crushed, and the gold recovered by washing and amalgamation. In earlier times, as later exploration proved, the shafts were sunk into the solid quartz, reaching a depth in some cases of 300 feet. Modern gold mining history dates from 1871, when Lavelle obtained the first concession and commenced a shaft on what is now the Ooregum Co.'s block. Between 1878 and 1882 various companies were formed, but by the end of 1884, most of them had exhausted their resources, and it was only a last effort on the part of the Mysore Company which in that year disclosed rich ore in some pillars left in an old mine. From that time the history of the field, under the capable technical direction of Messrs. John Taylor & Sons, has been one of practically uninterrupted success. The narrow belt of Dharwar schists on which the goldfield lies can be followed for about 50 miles from north to south, but the productive portion is confined to a length of about  $4\frac{1}{2}$  miles, on which are situated from north to south the Balaghat, Nundydroog, Ooregum, Champion Reef and Mysore mines belonging to the companies of the same names, though the Nundydroog Company acquired the property of the Balaghat concern in 1932. From the commencement of operations until the end of 1932 the total value of the gold won has been £75,180,497, while dividends amounting to £22,933,167 have been distributed. In the case of the Champion Reef Co. alone, the dividends paid in 1934 brought the total dividends above £5,000,000, on a capital of £260,000. This amounts to an average of 50 per cent per annum over a period of 40 years. The royalties paid by all the mines to the Mysore Government between 1882 and 1928

inclusive were £3,626,286. Practically the whole of the gold has come from the Champion vein, the average width of which varies from 2 to 4 feet. It strikes north and south and has a westerly dip of  $45^{\circ}$  near the surface, gradually steepening to almost vertical at the great depths now reached. The deepest point of the Champion Reef mine was 7,600 feet vertically below the surface in December 1934. In the vein itself the auriferous quartz occurs in separate ore shoots with intervening patches of low grade or barren ground. Development is carried out by means of levels at vertical distances of 100 to 150 feet, and the total footage of such workings to date amounts to over 480 miles. The gold content of the quartz is remarkably persistent with depth, and although individual ore shoots may come to an end, new ones are found to take their places. An example of this has been given recently by T. Pryor. In the southern part of the Champion Reef mine there was no ore of value for the 2,000 feet of depth between the 44th and 65th levels. At the latter level indications of a new ore shoot were found: this has since been followed for 1,000 feet of depth, and at the 75th level is 1,108 feet long, 46 inches wide and worth 21.6 dwt. of gold per ton. The gold production of the whole field for 1932 realized £1,925,593 and would have been worth £1,323,239 at normal prices. The peak of production was passed in 1905 with an output worth £2,373,457. The mines as a whole employ today some 330 Europeans and 23,000 Anglo-Indians and Indians, of whom about 12,000 work underground. The total population of the mining camp is approximately 58,750. Any definite pronouncement on the probable life of this important industry is impossible; improvements in mining technique will perhaps enable much greater depths to be reached, while there are no signs of impoverishment in the ore shoots at those already attained. Indeed, in 1934 it was officially stated that the appearance of the lode generally at the greatest depths then reached was considerably better than anything visible in the bottom of the Mysore mine for many years past. As far as can be foreseen there is nothing improbable in assuming that the Kolar goldfield will continue to be an important producer for many years to come.

Hundreds of old workings have been found scattered over the surface of the Dharwar rocks in Mysore, but it is reported that the enormous amount of modern work which has been done on them has proved conclusively that in the majority of instances they do not

indicate the existence of valuable deposits immediately beneath them. Equally disappointing has been the investigation of the numerous quartz veins which traverse the schists and crop out at the surface. Smeeth and Iyengar sum the matter up by saying: 'We may take it as an almost universal rule that outcropping veins are valueless.' After pointing out that it is possible that some zones of low grade ore may be found of sufficient extent and under sufficiently favourable conditions for cheap treatment to permit of their being worked, these writers conclude by saying: 'We cannot shut our eyes to the fact that the hopes based on the success of the Kolar mines and on the existence of numerous old workings in other parts of the State have dwindled very seriously with the progress of survey work and deep prospecting.'

In Hyderabad State auriferous quartz veins have been mined on a large scale at Hutti, Topuldodi and Wondalli, in the Raichur district. Old workings are numerous and in some cases deep, reaching 540 feet below the surface at Hutti, on an irregular area of Dharwar rocks which stretches through Maski, from the vicinity of the Tungabhadra river to the Kistna. A company mined at Wondalli between the years 1891 and 1900 and the yield of gold from the State from 1898 to 1900, amounting to £54,310, was almost exclusively the produce of this concern. Crushing commenced at Hutti in 1903 and ceased in 1920, after the mine had reached a depth of 3,500 feet and gold worth £1,010,757 had been extracted. The only recorded production from Topuldodi, which commenced in 1905, was worth £8,319 in 1908, when the mine was closed down. The Hutti (Nizam's) Gold Mines Ltd. was an offshoot of the Hyderabad Deccan Company and the two smaller ones were its subsidiaries.

In 1874, R. B. Foote found an auriferous quartz vein near Dambal, Dharwar district, Bombay, on the great belt of Dharwar rocks, known as the Dambal-Chiknayakkanhalli, or Gadag band, which stretches from the southern part of the Bombay Presidency into southern Mysore. Abundant ancient workings exist in the neighbourhood. The area was prospected between 1902 and 1904 and crushing was commenced in 1907 by the Dharwar Reefs Gold Mining Co. Ltd. Other companies took up concessions both in the Dharwar district and in the adjoining State of Sangli, but the veins proved too poor to work profitably and mining was abandoned in 1911, when the Dharwar Reefs mine had reached a depth of 950 feet. The total

production from this field was worth £80,209. There are two parallel series of veins about  $3\frac{1}{2}$  miles apart, with numerous individual veinlets of no great size or extent; the eastern series is traceable north-north-west, south-south-east for eight miles and is associated with carbonaceous argillites. The country rocks of the western group are talc and chlorite schists.

A belt of Dharwar schists stretching north and south through the Anantapur district of Madras contains several large quartz veins associated with chloritic and argillaceous schists. The presence of old workings near Ramgiri led in 1905 to the formation of the Anantapur Gold Field Ltd., and in 1908 to the North Anantapur and Jibutil Gold Mines companies with mines of the same names. At the former a depth of 1,150 feet was reached by 1924, when operations ceased after yielding gold to the value of £782,023.

The Chota Nagpur division of Bihar and Orissa is traversed from east to west by a series of argillites, phyllites, talc and mica schists of Dharwar age which enclose quartz veins of the two types mentioned earlier, but the gold is here found, as a rule, in the opaque white and younger veins. Many altered basic intrusives related to epidiorites occur in the gold-bearing areas. Both veins and old workings are very numerous, and small amounts of alluvial gold occur in most of the streams, where its extraction on a small scale by the primitive tribes of Singhbhum is indeed still carried on. In 1890 a gold boom, centred on this region, occurred in Calcutta, and 32 companies with a total capital of nearly £1,000,000, were formed, following the discovery of rich ground in the Sonapet valley in 1888, but by the end of 1892 only two remained in existence. Later investigations by J. M. Maclaren proved that the gravels are too low in gold values to be worked profitably. Various localities are known in which auriferous quartz veins occur, but in this case again, assay results have been uniformly poor, though favourable territory for further prospecting is believed to exist. The distribution of the gold-bearing veins of Singhbhum suggests, according to J. A. Dunn, a relationship with the late basic intrusive phase of the Dalma volcanic rocks. The discovery of old workings near Kundrukocha, in Dhalbhum, close to the Mayurbhanj border, on a series of veins of blue-grey quartz in Dharwarian phyllites, led to the formation of the Dhalbhum Gold & Minerals Prospecting Co. Ltd., which recovered 6,034 oz., valued at £26,839, between the years 1915 and 1920. All

but about 250 oz. of this came from one pocket at Porojarna. According to Sir Lewis Fermor, the richer veins only average about 4 dwt. to the ton, though the Porojarna shoot averaged about 20 dwt.

The gold occurrences of the Mingin hills in Upper Burma, though of no commercial value, as far as is known at present, are of interest in that they furnish an example of the occurrence of the metal entirely different from that found in the Dharwarian rocks of the Indian peninsula. The hills which lie between the Mu and Meza streams, both tributaries of the Irrawaddy, are, according to F. Noetling, formed of eruptive volcanic rocks. Five localities are known on the eastern flanks where veins containing auriferous pyrites occur, and three others where the mineral has been mined by the Burmese from volcanic ash. One of the veins was mined near Kyaukpazat between 1898 and 1903, when the pay shoot was lost and the enterprise abandoned. The vein averaged  $3\frac{1}{2}$  feet in width, 240 feet in length and was followed to a depth of 420 feet. It was occasionally clean but more often well mineralized, carrying 5 per cent of chalcopyrite, pyrite, galena, franklinite and small amounts of altaite, the telluride of lead. The country rocks were tuffs and breccias of andesitic facies, intruded in places by quartz diorites. The total production from the Kyaukpazat mine was probably worth between £19,000 and £20,000.

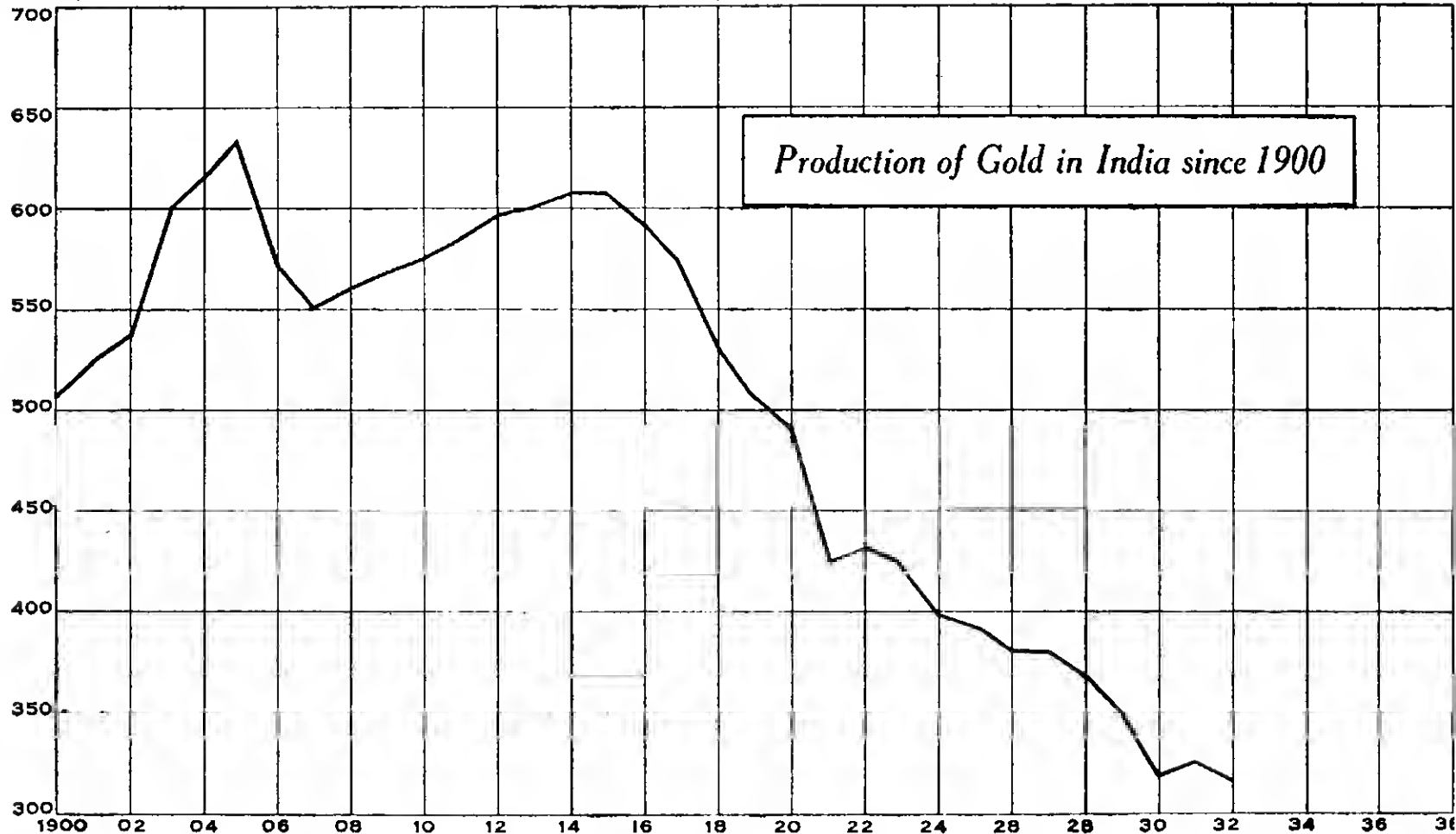
Alluvial gold is found in the sands of many Indian rivers, in fact, as La Touche points out, there is hardly a province in which its recovery from river sands is, or has not been practised by the inhabitants, though the quantity won in this way is insignificant. In the case of the rivers draining the Indo-Gangetic plain, including the valley of the Brahmaputra in Assam, the metal is derived, not from the rocks which were its original home but from others into which it was introduced along with the transported material of which they are composed. Regular returns of production amounting to a few ounces annually come from the Singhbhum district of Bihar and Orissa; from the Katha and Upper Chindwin districts of Burma; from Kashmir, where washing is carried on along the Indus valley in Gilgit and Baltistan; from the Punjab, where it is practised in the Attock, Ambala and Jhelum districts; and from British Garhwal and the Bijnor district of the United Provinces. The returns, such as they are, are believed to be incomplete. The alluvial miner is as often as not a cultivator who adds to his meagre income by the speculative



pastime of gold washing, when the crops do not demand his immediate attention. The small quantities of the precious metal so obtained in most cases probably find their way direct to the village goldsmith to be turned into ornaments. Dr J. M. Maclaren, who made a searching investigation of the whole subject, concluded that in few countries is alluvial gold more widely distributed than it is in India, and in few countries also does it show less tendency to aggregation under the influence of running water. He pointed out that wherever streams drain areas of ancient schistose rocks and possess the proper gradients for the deposition of gravel, they carry small amounts of alluvial gold. Such conditions apply in many parts of Mysore, Madras, Bombay, Hyderabad, Central India and Chota Nagpur, and to these we may add Burma and the Federated Shan States, parts of the Upper Indus valley and certain tributaries of the Brahmaputra in Upper Assam, 'but in no case,' writes Dr Maclaren, 'so far as is yet known, are the gravels sufficiently rich to warrant European examination, though they may in many cases afford a few weeks' employment during the cold weather to the native washer, who is content to work for a return of  $1\frac{1}{2}$  to 2 pence per day'. Maclaren's own investigations in the richest streams of Chota Nagpur proved that the alluvial ground contained on the average about 1 to  $1\frac{1}{2}$  grains of gold per cubic yard, and that the six inches or so of the bottom gravel, which under normal circumstances would naturally be the richest, yielded not more than 2 grains per cubic yard. The great regular seasonal changes from the low waters of the dry weather to the raging floods of the 'rains', which characterize rivers subject to the periodic variations of a monsoon climate, are not conducive to the tranquil conditions necessary for the accumulation of thick gold-bearing gravel deposits.

The pioneers of gold dredging in Burma were W. R. Moore and J. Terndrup, through whose enterprise a company was formed which carried on operations in the upper reaches of the Irrawaddy and its branches the N'maikha and the Malikha, in the Myitkyina district, between 1903 and 1918. The average value of the gravels was about 3 grains per cubic yard, and a total of 56,624 oz. of gold, worth £217,381, was recovered, together with small quantities of platinum and its associated metals. The dredgers were eventually removed to the Tavoy district and helped in the successful inauguration of the tin dredging industry there.

THOUSAND  
OZ. (TROY)



Graph 5

The Mandalay Gold Dredging Co. Ltd. obtained a large concession in the Lower Chindwin river between Minsin and Homalin, but the dredger dispatched there in 1905 was wrecked on the way, and the undertaking abandoned.

In 1905, a dredger erected on the Namma river, a tributary of the Salween in the Northern Shan States, where preliminary exploration is alleged to have proved the existence of approximately 40 million cubic yards of gravel, with an average value of 5.43 grains of gold per cubic yard, was found unable to perform its task owing to the cementation of the gravel by calcium carbonate. Such systematic prospecting of the alluvial gold-bearing deposits of Burma as has been undertaken has proved in most cases that they are too poor to hold out hopes of successful dredging. It is possible, however, that better ground remains to be discovered, especially in the upper branches of the Irrawaddy and Chindwin and of their tributaries.

## SILVER

Many of the lead ores which occur scattered over the Indian Empire in small quantities are argentiferous, but none of them has yet proved of any economic importance with the exception of those of Bawdwin in the Northern Shan States (see LEAD). As a rough guide to the relations between the amounts of lead and of silver present in the Bawdwin ore, it may be taken that the general mixture of galena and zinc blende there contains approximately 1 oz. of silver for every unit per cent of lead. Actually from the extracted ore an average of 1 oz. has been obtained for every 1.1 per cent of lead. It is instructive to trace the silver in its passage from the mine to the refinery, for the treatment of the crude ore in the milling process results in an increased percentage of silver in some of the products and a smaller amount in others. For example, in 1932, the ore delivered to the mill from the mine contained:

Silver, 20.5 oz.; Lead, 24.93 per cent; Zinc, 12.76 per cent.

In the following table, the composition of some of the products made in the mill from this ore is shown, all of which, with the exception of the zinc concentrates exported to Europe for treatment, are smelted on the spot.

COMPOSITION OF PRODUCTS FROM THE MILLING  
OF BAWDWIN ORE

PRODUCT	ASSAY VALUE			
	Silver	Lead	Zinc	Copper
	oz.	%	%	%
Coarse Concentrate ...	45.86	65.03	9.10	0.33
Float Concentrate ...	40.24	70.18	7.32	0.50
Copper Concentrate ...	135.70	34.77	13.06	9.85
Iron Concentrate ...	11.52	14.41	12.15	0.57
Zinc Concentrate ...	9.02	6.01	51.66	...

These assay figures show how the silver is associated with the lead and the copper rather than with the zinc.

A series of average assay values of some varieties of hard lead and of the copper matte produced by smelting these concentrates is given in the next table.

COMPOSITION OF SOME SMELTER PRODUCTS  
FROM BAWDWIN ORE

SOURCES OF HARD LEAD	SILVER	LEAD	COPPER
	oz.	%	%
Hard Lead from Ore ...	68.13	96.92	...
Hard Lead from Copper Concentrates ...	301.67	94.88	...
Hard Lead from Iron Concentrates ...	72.05	94.84	...
High Grade Copper Matte ...	82.29	27.72	43.67

The silver is finally recovered from the hard lead in the refinery, where the Parkes' process is in use.

The growth of silver production at Nam Tu can be judged from the following table, in which the total number of ounces extracted in each quinquennial period from the commencement of such operations is given.

*TABLE VIII*  
**PRODUCTION OF REFINED SILVER AT NAM TU**

PERIOD			
		oz.	£
1909-13	...	399,715	46,460
1914-18	...	4,831,504	679,222
1919-23	...	17,639,125	3,189,110
1924-28	...	28,632,070	3,766,634
1929-33		32,288,126	2,718,282
Total	...	83,790,540	10,399,708

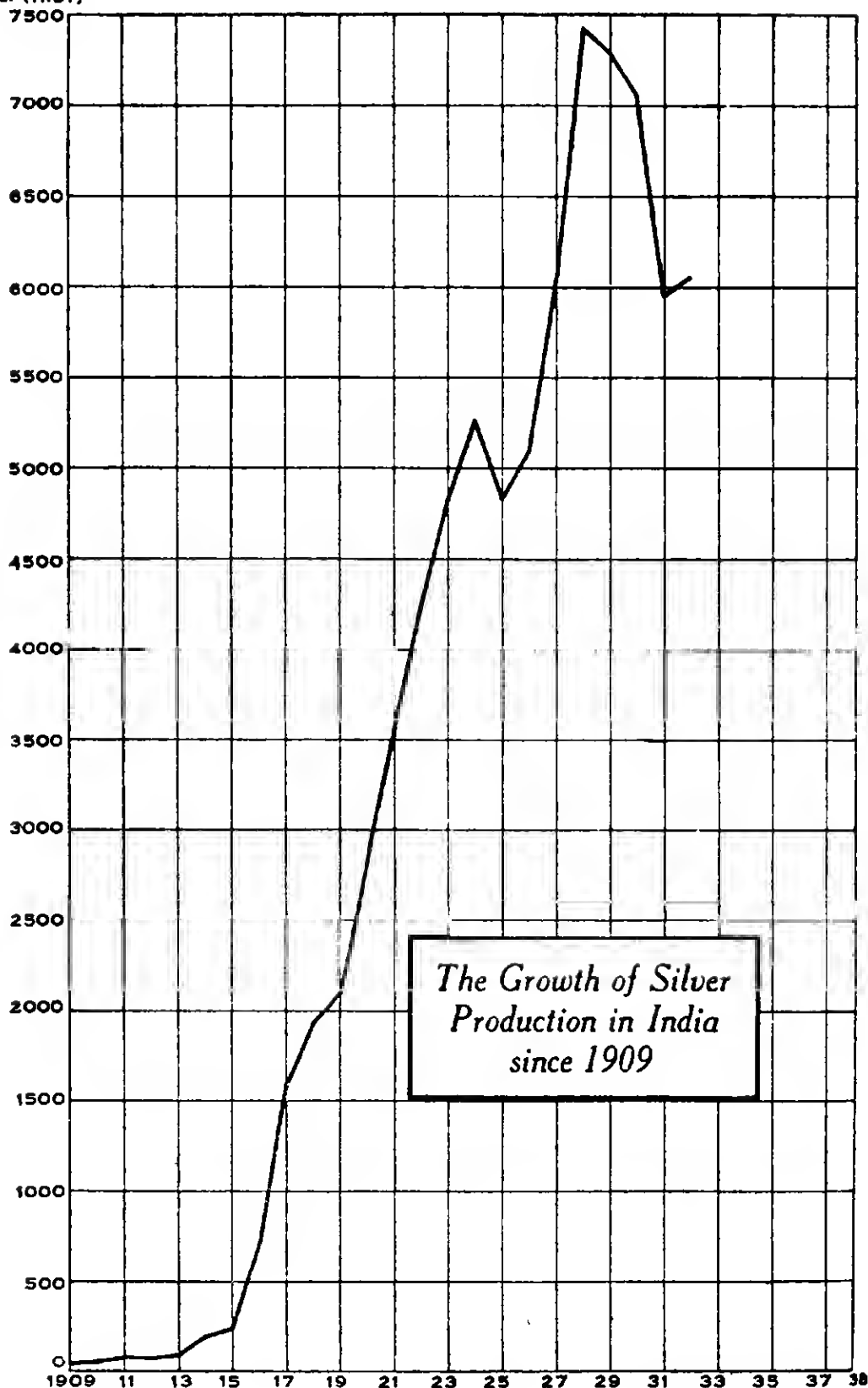
Large though these figures are, they do not represent the total quantity of silver yielded by this great mine, for varying small amounts remain in the zinc concentrates which are doubtless recovered later in the countries to which they are destined, while the copper matte which is exported for further refining contains a great deal. In the 96,933 tons of matte, valued at £2,488,936, produced from the commencement of this branch of activity in 1924, until the end of 1932, the average silver content per ton has never fallen below 63 oz. and has more recently approximated 85 oz.

The maximum silver production was attained in 1928, with 7,404,728 oz., which were worth £890,004. In later years somewhat smaller amounts have been extracted, as a natural result of the deliberate reduction of the through-put of lead ore.

India, with its vast consumption of metallic silver in normal years, is the natural market for the Burmese metal, and in 1932, for the first time in its history, the Burma Corporation failed to dispose of its silver in India. The monthly production was therefore shipped to England for sale in the open markets of the world.

The gold from the Kolar field of Mysore nearly always contains some silver which is recovered in refining operations, and small quantities of similar origin were obtained from the Jibutil mine in the Anantapur district, Madras, during its active life. The available statistics of the silver derived from these sources are summarized below.

THOUSAND  
OZ. (TROY)



*The Growth of Silver  
Production in India  
since 1909*

Graph 6

TABLE IX  
SILVER RECOVERED FROM INDIAN GOLD  
REFINING

PERIOD	ANANTAPUR GOLDFIELD		KOLAR GOLDFIELD	
	oz.	£	oz.	£
1915-18 ...	4,324	607	...	...
1919-23 ...	2,895	531	124,940 <sup>1</sup>	22,589
1924-28 ...	478 <sup>2</sup>	47	109,781	14,060
1929-33 ...	...	...	112,212	11,576

## PLATINUM

It is over 100 years since James Prinsep proved that a button of white metal sent to the Asiatic Society of Bengal in 1831, from Ava, in Upper Burma, contained large quantities of platinum and the related metals osmium and iridium. Major Burney, the first British Resident in Ava, later explained how it was obtained from streams which enter the Chindwin from the west near Kanni. H. S. Bion, who examined the gold-bearing alluvial deposits of the Chindwin and its tributary the Uyu in 1912, reported that platinum with osmiridium was detected in almost every locality, but in very small amounts, its mode of occurrence being the same as that of the gold. In 1927, H. L. Chhibber investigated alluvial gold workings in another portion of the Uyu valley in the Myitkyina district, and found small quantities of platinum as a constant associate of the gold. It is carefully removed from the gold concentrates by the local inhabitants and thrown away.

Platinum and iridosmine then are characteristic associates of the alluvial gold of the extreme north of Burma, and it is not surprising therefore to find that the metal was regularly recovered by the Burma Gold Dredging Co. during its treatment of the gravels of the Irrawaddy and its branches above Myitkyina, between 1903 and 1918. The records are probably incomplete, but they show a recovery of 219 oz., valued at £1,332, between 1911 and 1914.

It is more than a coincidence that platinum and iridosmine were identified by Mallet in 1882, accompanying gold in the sands of the

<sup>1</sup> For four years only. Statistics commenced in 1920.

<sup>2</sup> For four years only. No production in 1928.

Noa Dihing, a river which drains the opposite flanks of the Patkoi range in Assam. The distribution of the occurrences generally leads to the hypothesis that the metals come from the great serpentine intrusions of the Patkois and the Arakan Yomas.

Platinum is always associated with one or all of the metals of the group to which it belongs. These are palladium, iridium, rhodium, ruthenium and osmium. Platinum, owing to its resistance to heat and chemical attack, provides the chemist with both laboratory and works utensils. It serves as a catalytic agent in the contact process of sulphuric acid manufacture, alloyed with rhodium in that of nitric acid, while palladium is used in the reduction and hydrogenation of organic compounds. Some of the platinum salts find applications in the production of photographic papers, but the use of the metal for 'lead-in' wires in electric light bulbs has ceased. The chief outlet of the metal today is in the jewellery trades, where either alone or hardened by alloying with iridium it is used for mounting gems. The so-called 'white gold' of jewellery and dentistry is a palladium-gold alloy, though not the only one to bear this name. Platinum and palladium are also used for watch cases and in the form of foils to take the place of gold where white, non-tarnishing, decorative surfaces are required. These two metals, together with rhodium, are used to electro-plate fine jewellery. A. H. Robinson of the Canadian Department of Mines has recently given the following summary of other industrial applications of these precious metals (1934). 'In the electrical trades, palladium and iridium-platinum, ruthenium-platinum, palladium-silver and platinum-gold-silver alloys are used for contacts in such instruments as thermostats, magnetos, telephone relays, etc.; platinum, palladium, rhodium-platinum and platinum-nickel alloys for resistor and high temperature purposes in thermocouples, high-temperature thermometers, vacuum-tube amplifiers, electrical detonators and for heating elements in electrical furnaces. Platinum, palladium and rhodium are used for electro-plating table utensils such as electric percolators, toasters, etc. Platinum-gold alloys are made into spinnerets in rayon manufacture and platinum-rhodium alloys into heater windings for combustion and porcelain furnaces. In dentistry, iridium-platinum and platinum-gold alloys are used for pins, lingual bars, etc., and palladium alloys for high-grade dentures or plates. Iridium-platinum alloys are also formed into hypodermic needles and cauteries.' Osmium, the heaviest metal



known, occurs naturally alloyed with platinum in the substance osmiridium which is used for tipping the nibs of gold pens. Thirty years ago the cost of platinum was a little less than that of gold, but by 1920, probably owing to its introduction into jewellery, it was valued at seven or eight times the price of gold. In later years its price has decreased greatly and in August, 1935, the refined metal was quoted at £7 per oz. Iridium is worth between £9 and £10 per oz.; palladium, the cheapest metal of the group, about £4 per oz. and osmium between £7 and £9 per oz. The chief producing countries in order of importance are Russia, Canada, the Union of South Africa and Colombia.

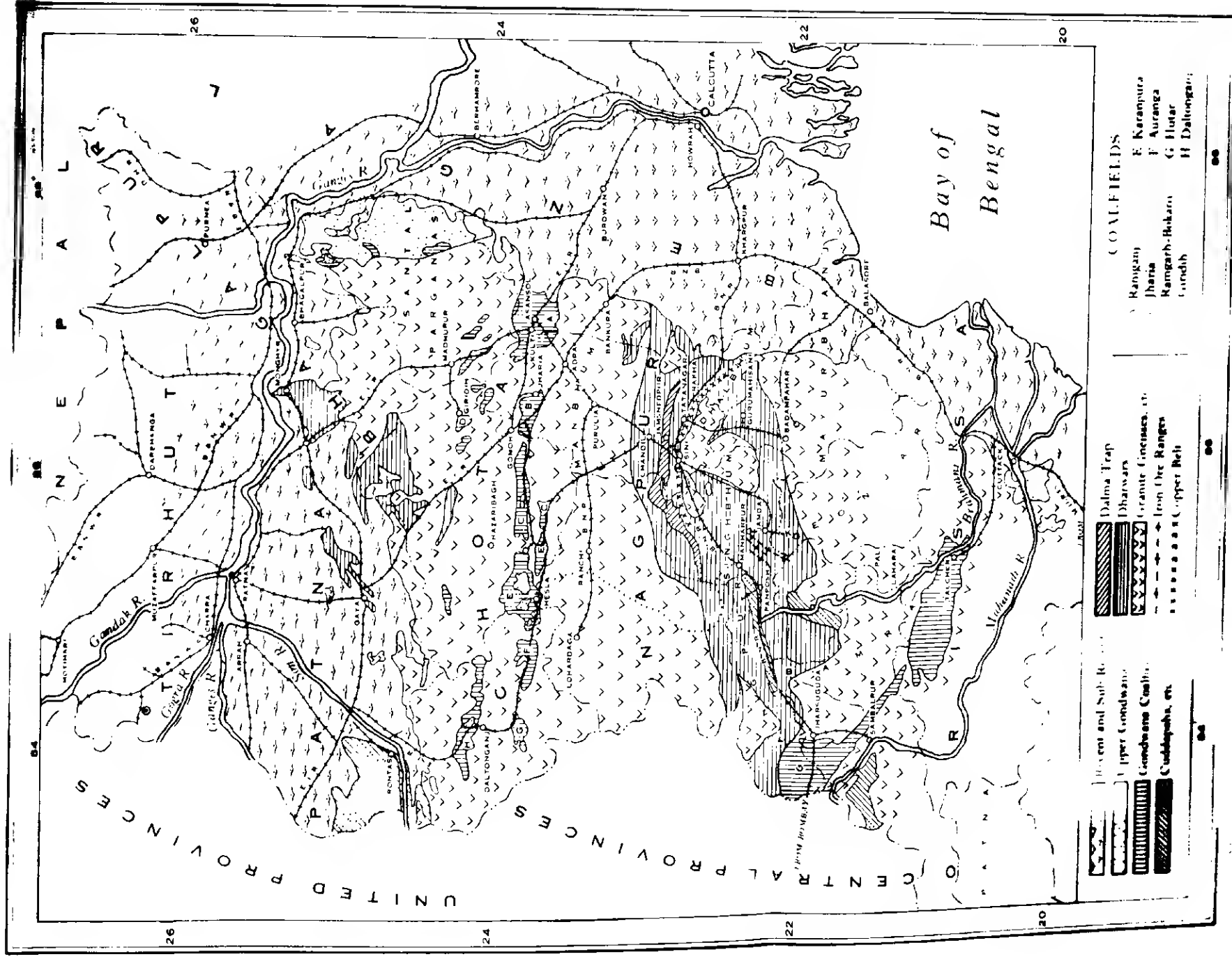
## CHAPTER III

### COPPER, LEAD, ZINC AND TIN

#### COPPER

THE copper ores of peninsular India, as V. Ball first pointed out, occur both in the older crystalline rocks and in several of the younger groups, as, for example, in those of Cuddapah, Bijawar and Aravalli age. In extra-peninsular India they are found for the most part in highly metamorphosed rocks, the precise age relationships of which are not in all cases quite clear as yet. The commonest ore is the sulphide of copper and iron, copper pyrites, but near the outcrops it is usually altered into the carbonates malachite and azurite. As a general rule, to which there are however some exceptions, Indian copper ores are not found in true lodes, but are either sparsely disseminated or are locally concentrated in more or less extensive bunches or nests in the enclosing rocks; occasionally cracks and small fissures traversing the strata have been filled with infiltrated ore and thus resemble true lodes. Copper-bearing minerals have been reported from practically every province and there are both in the peninsular and extra-peninsular regions mines of great extent whose histories are completely lost. Copper ores were smelted in pre-historic times and may have supplied the needs of the country for many later centuries, but in the days of early European contact with India, the mining and smelting of copper ores appears to have fallen to quite a small scale, and fifty years ago was only carried on in the most petty manner. In the majority of cases, Ball states, the miners were unable to cope with the water which flooded their workings, and in spite of the fact that their earnings were small, the metal which was turned out by the smelters could not be sold at a price which would enable it to compete in the regular markets on equal terms with metal imported from abroad. Only the larger occurrences of copper ores can be dealt with here.

In the Singhbhum district of Bihar and Orissa, a copper-bearing belt with many ancient workings commences near Duarparam in the



west and passing through Kharsawan, following in a remarkable manner the strike of the country rocks, curves round to the south-east through Seraikela into Dhalbhum, reaching Baharagora, a distance of approximately 80 miles, on the borders of Mayurbhanj. The copper belt, according to J. A. Dunn, lies mainly within a sequence of Archæan rocks known as the Iron Ore series. The lower part of this consists of shales and sandstones, metamorphosed into phyllites and mica schists, quartzites and granulites. In the upper part are metamorphosed tuffs and the basaltic flows known as the Dalma lavas. The rocks are strongly folded, and a great overthrust zone has developed along the southern overfolded limb of the main, central geo-anticline. While these events were taking place, vast granitic batholiths invaded the series and tongues of the same material ascended part of the thrust zone itself, to be caught in the later stages of the overthrusting and in places completely mylonitized. Elsewhere the granite is traversed by shear planes.

The mineralization associated with the later phases of the granite intrusions, confined mainly but not entirely to the thrust zone, is responsible for two principal types of veins: one consisting of copper and other sulphides and the other of apatite and magnetite. The severe shattering of the rocks has, as a rule, prevented the concentration of the minerals within veins big enough to be mined profitably, but this does not hold for the important section of the belt between Rajdah and Badia, where the overthrust movements, concentrated into a narrow zone, have resulted in well defined fractures and easier channels for the ascension of ore-bearing solutions. Thus payable lodes occur in granite, epidiorite and quartzite. The lodes are described by Dunn (1934) as consisting in places of a narrow core of sulphides merging into a vein rock of quartz, often containing apatite, magnetite, biotite, chlorite, sericite and sulphides. All these may also occur in variable proportions in the wall rock, extending the width of the lode. Apatite, magnetite and quartz were the first to form, followed by pyrite, pentlandite, pyrrhotite, violarite, millerite and chalcopyrite. There is no zone of enrichment, and the products of supergene alteration give place gradually to normal primary sulphides, usually within much less than 200 feet.

Sir Lewis Fermor in 1911 was the first to suggest that the granite was the source of the mineral-bearing solutions which gave rise to the copper ores, while J. M. Maclaren, in 1904, tended to connect

them with the epidiorites, some of which he regarded as intrusive. Dr J. A. Dunn's most recent work leads to the conclusion that both the magnetite-apatite veins and the closely associated copper deposits are high temperature liquations from the same residual soda granite magma, the latter phase being older in time than the former, while relief of pressure, rather than falling temperature, was the controlling factor in the process.

The first allusion to the ores was made in 1829, and mining operations were commenced at Landu and Jamjura in 1857, but no success was attained either by this or succeeding ventures until comparatively recent times. During the years 1906-08, selected localities on the copper belt were systematically drilled by the Geological Survey of India, a campaign which directed renewed attention to the problem and led to the acquisition by the Cape Copper Co. of the Rakha Hills mines near Matigara, which had been worked by the Rajdoha Copper Co. from 1891 to 1908. The property was actively developed, large reserves of ore were proved, and a mill, smelter and refinery erected. Smelting commenced in 1918 and continued until March, 1923, when work was stopped after the production of 180,095 tons of ore, valued at £224,702, from which 3,550 tons of copper, worth £319,381, had been made.

The Cordoba Copper Co., under the management of John Taylor & Sons, commenced prospecting on the Mosaboni area, farther to the south-south-east, in June, 1920, and soon met with promising results. Another company under the same control, the North Anantapur Gold Mines Ltd., commenced on the adjoining Sideshur-Kendadih area in 1922, while the Ooregum Gold Mining Co. Ltd. sank shafts and discovered a lode to the south of Galudih in Kharsawan State. In 1924, the Indian Copper Corporation Ltd., as a reconstruction of the Cordoba Copper Co. Ltd., took over its mining rights in Singhbhum, together with those over the area containing the Kharsawan mine and an option to purchase the Sideshur concession. The Corporation's leases now extend over 6,900 acres and include the Mosaboni, Dhobani, Surda and other mines. Attention is at present being chiefly directed to the Mosaboni and Dhobani mines, where at the end of 1934 the ore reserves amounted to 932,143 short tons, containing 3.10 per cent of copper, an estimated content of 28,860 tons. Recent field work by J. A. Dunn (1934) suggests that west of Mosaboni there is a possibility of a continuous mineralized

zone adjacent to the western edge of the soda granite, which deserves prospecting. The outlook for the future of the Dhobani mine is bright, while in the granite north-west of Baharaghora there are several lines of old workings sufficiently attractive to warrant exploration. The power plant, mill and smelter are situated at Moubhandar, close to the Bengal-Nagpur Railway and the Subarnarekha river, and are connected with the mine by an aerial ropeway five miles long. Smelting commenced in December, 1928, and a rolling mill was installed in July, 1930. Between 1925 and 1933 the Mosaboni mine has yielded 789,826 tons of copper ore valued at £900,776, and in 1934 it delivered 353,310 tons of dry ore to the mill. The total amount of refined copper made up to the end of 1934 was 24,221 tons, the production for that year being 6,300 tons, as compared with 4,800 tons in 1933. Practically the whole of the copper is now converted into yellow metal sheets and circles which are marketed in India, and in 1934, 7,221 tons of the former and 959 tons of the latter—a total of 8,180 tons of yellow metal products—were manufactured.

The successful foundation of copper mining, smelting and refining, together with the inauguration of the rolling mills, by the Corporation, are the most important events in the development of India's mineral industry during the last decade. There are indications that the lodes now mined will persist to considerable depths and the discovery of new ones is probable. When the extent of the Indian markets for copper and brass goods is considered, the outlook for the future of copper mining and metallurgy seems particularly encouraging, for the average annual value of India's consumption of imported copper and brass reaches high figures. It rose from £1,352,015 in the period 1904-06 to a maximum of £3,602,885 in the years 1919-20 to 1923-24, falling to £2,777,319 per annum for the five years ending 1927-28 and to £2,276,872 (representing 34,670 tons of materials) in the quinquennium ending 1932-33. In addition to this, over the five years ending 1933, India spent on an average over £658,000 annually on imported electric wires and cables, into the composition of which metallic copper largely enters. In spite of the fact that certain products of this description are now manufactured in India, the value of the foreign imports for a normal year has been considerably over one crore of rupees.

In the notes on LEAD and ZINC it is stated that chalcopyrite occurs with the lead-silver-zinc sulphides at Bawdwin in the Federat-

ed Shan States (see Plate I), more especially in the northern or 'Shan' portion of the great orebody there. As a rule it is found so intergrown with the other ores that it cannot be mined separately, so that any voluntary curtailment of the lead output is reflected in an automatic decrease in the supplies of copper ore. Recent exploration in the southern or 'Maingtha' section of the orebody has revealed promising developments of high grade copper ore, especially in the deeper levels of the mine. The copper is recovered in the course of concentrating and metallurgical operations at Nam Tu and is exported to Europe in the form of matte, which in addition to some 40-44 per cent of copper contains approximately 30 per cent of lead and 70-80 oz. of silver to the ton. The production of this material was first reported in 1924, and from that time until 1931, 87,204 tons had been shipped, valued at £2,339,951. It is estimated that they contained 36,145 tons of metallic copper. The present annual production of the matte averages about 11,000 tons.

Extensive ancient copper workings exist at Baraganda, Hazaribagh district, Bihar and Orissa, in quartzites associated with gneiss and mica-, talc-, and hornblende schists, through certain bands of which copper pyrites with a little galena and zinc blende are disseminated. The copper content appears to be low and several attempts to reopen the old mines, spread over the last 70 years, have been unsuccessful. In 1888, the Bengal Baragunda Copper Co. produced 218 tons of refined metal.

Low grade ores have also been smelted by native methods in the past in the Darjeeling district, where copper pyrites is found in some localities disseminated in the slates and schists of the Daling series; in Kumaon and Garhwal, and in the Kangra Valley, but the value of the deposits concerned is quite problematical.

There are many records of ancient mines in Madras, Central India and Rajputana. In the Chitaldrug district of Mysore, chalcoppyrite occurs in a felsite cutting the Jogimaradi trap, at Ingladhui, under geological conditions recalling those of the Singhbhum and Dhalbhum regions. The Singhana, Khetri and Babai mines of Jaipur State, Rajputana, are almost continuous for 15 miles in the upper part of a zone of slates and schists of Ajabgarh age and are now in a ruinous, water-logged condition. Nevertheless A. M. Heron believes that ore still exists in sufficient quantities to justify reopening, drainage and proper prospecting, offering possibilities of a large, low-grade undertaking.

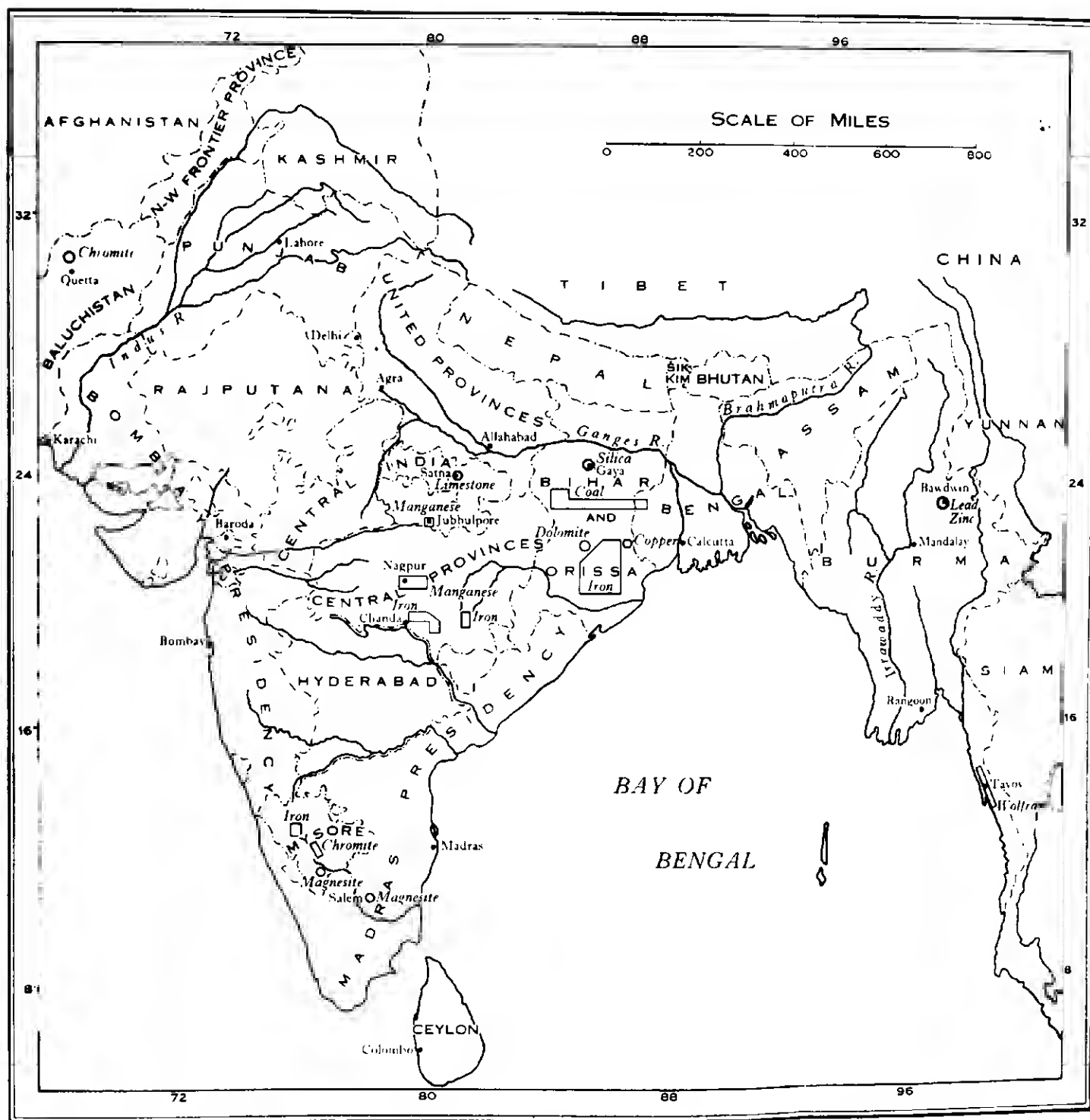
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India's Mineral Wealth, facing p. 90

From the Mining Magazine, 1921

Map VI

INDIA, SHOWING APPROXIMATE POSITIONS OF CERTAIN MINERAL-BEARING AREAS

1,35,41,689 are issued, and gives some impression of the magnitude of the undertaking.

In the neighbourhood of Bawdwin, a series of rhyolitic tuffs, lava flows and breccias, with coarse felspathic grits, of early Palæozoic age, has been intensely crushed and disturbed by overthrust faulting. Within this zone, intimately connecting with the faulting, lies a well-marked ore channel, at least 8,000 feet long and 400 to 500 feet wide, and within the ore channel again, so far as it has been developed, three major orebodies, once united but now separated by cross faults, have been found. They are believed to have been deposited by ore-bearing solutions which perhaps originated from a deep underlying granite magma, and metasomatically replaced the minerals in the congenial rhyolitic tuffs. The central orebody—the Chinaman—is a huge, lenticular replacement, on the hanging wall side of the channel. It has been developed for over 1,000 feet in length and to a greater depth. It varies in width from a few feet to over a hundred feet of solid ore, maintaining on some levels an average width of 50 feet over a distance of 1,000 feet. It is a fine-grained intimate mixture of galena and zinc blende, with chalcopyrite in places, often in parallel bands. The galena-zinc blende intergrowth contains approximately one ounce of silver for every per cent of lead. On both sides of the central core are alternating bands of solid ore and mineralized tuff, forming a kind of stockwork, and there is no sharp boundary beyond this, particularly on the foot wall side, where sparser mineralization often continues considerable distances before barren rock is reached. The mining limit is arbitrarily fixed as ore containing 20 per cent combined lead and zinc, and if this is ever lowered, very large amounts of lower grade ore will be added to the reserves. The orebody diminishes in thickness and tends to split in depth as it approaches a band of underlying sediments at No. 10 level, below which it has not been found.

The Shan orebody is the northern faulted extension of the Chinaman, offset towards the east by the Yunnan fault, and as there is a prevalent northerly pitch, the thicker portions of it occur at greater depths. In the northern end of the Chinaman body, zinc tends to be partially replaced by copper and the Shan orebody is characterized by additional copper ore and higher silver values in places. It extends down to No. 11 level.

The Maingtha orebody lies beyond the Hsenwi fault to the south of

the Chinaman. Discovered in 1929, it is still under active exploration and has already added large additional tonnages to the reserves.

The main way into the mine is by Tiger Tunnel, 7,250 feet long, 653 feet below the zero level at Bawdwin itself and corresponding to the sixth level of the shafts there. Marmion's shaft, which is sunk from the surface in the country rock on the west of the Shan ore-body, has 14 levels at intervals of 120 to 150 feet apart.

The mine is connected with the smelter at Nam Tu, 13 miles distant, and with the Burma Railways at Nam Yao, 46 miles away, by the Corporation's own railway. There are five blast furnaces with their attached roasting plant, as well as the refinery in which the silver is separated from the lead. A new mill and flotation plant were completed in 1920 and have a capacity of 800 to 1,000 tons per day. Hydro-electric power is derived from the Mansam falls on the Nam Yao river.

In the following table the total quantity of lead extracted from Bawdwin ores in Burma from the commencement of operations in 1909 up to the present time, is shown in quinquennial periods.

*TABLE X*  
PRODUCTION OF LEAD AT NAM TU

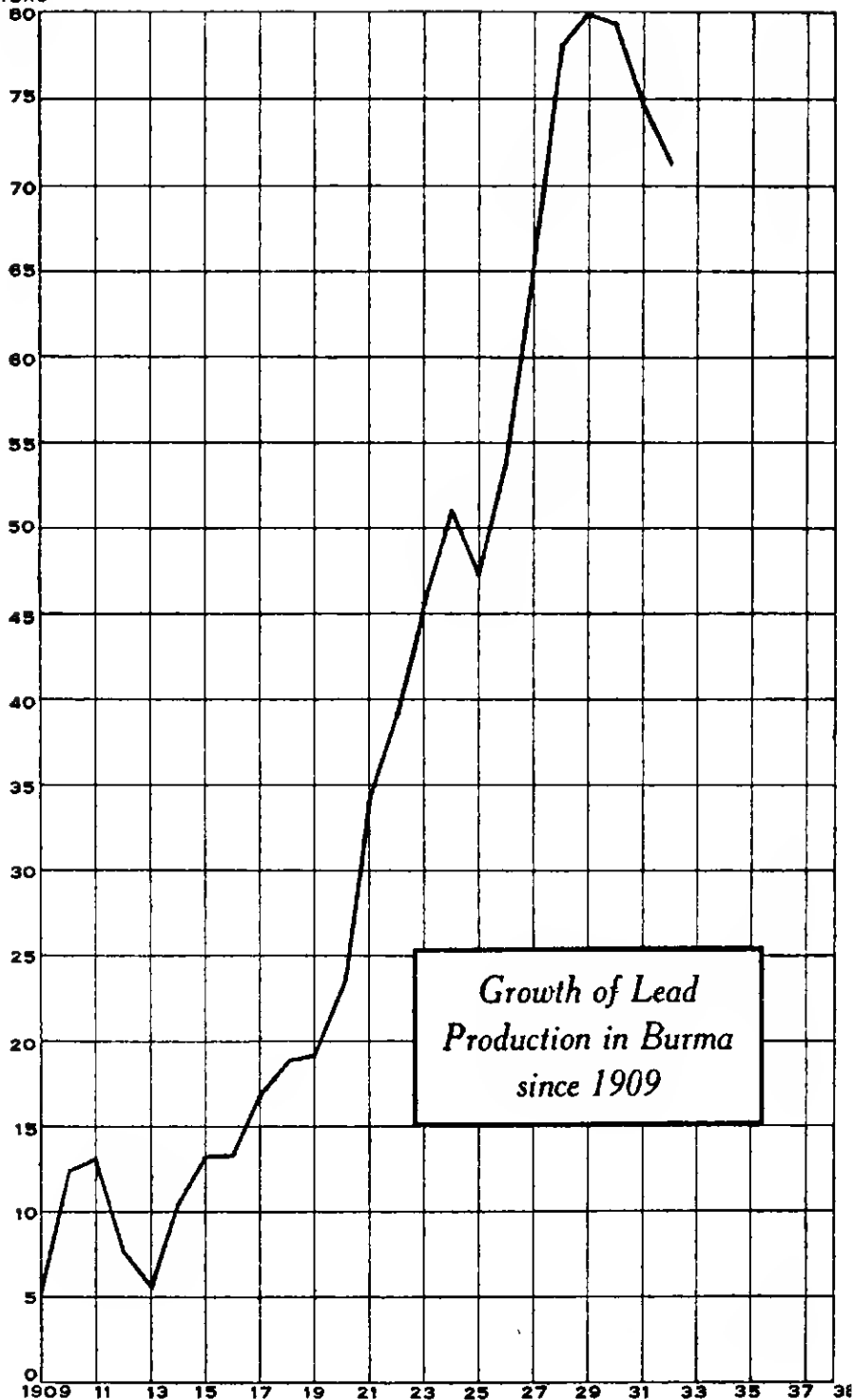
PERIOD	TOTAL TONNAGE	STERLING VALUE
1909-13 ...	45,550	632,505
1914-18 ...	73,817	1,792,345
1919-23 ...	161,902	4,405,718
1924-28 ...	297,715	8,340,471
1929-33 ...	377,995	5,887,169
<b>Total ...</b>	<b>956,979</b>	<b>£ 21,058,208</b>

These figures include antimonial lead of which 1,485 tons were produced in 1933. The largest annual production was reached in 1929, with 80,233 tons of lead, worth £1,865,717, and since then the tonnages extracted have been slightly lower.

This falling off is officially stated to be due entirely to the necessity of regulating production, in order to minimize the depressing influence on market conditions of a further increase in the stocks of unsold metal, which would have been unavoidable in the absence of demand as a consequence of the world depression.

THOUSAND

TONS



*Growth of Lead  
Production in Burma  
since 1909*

Graph 7

The following table shows the quantities and compositions of the reserves of the various orebodies on 1 July 1932. At the end of 1934, the reserves totalled over 4,000,000 tons, or more than nine years' supply at the present rate of extraction.

### ORE RESERVES OF THE BAWDWIN MINE ON 1 JULY 1932

		AVERAGE ASSAY VALUE			
		Silver	Lead	Zinc	Copper
	<i>Tons</i>	<i>Oz.</i>	%	%	%
Total Chinaman Orebody (Proved and Probable) ...	6,038,245	22·2	26·2	16·6	0·50
Total Shan Lode ...	1,995,762	18·9	22·6	10·7	2·33
Total Meingtha Lode ...	533,234	13·6	16·9	12·4	0·83
Total (Proved and Probable) ...	8,567,241	20·9	24·8	14·9	0·92
Extracted ...	4,441,062	22·0	24·3	14·3	1·15
Reserve in Mine... ..	4,126,179	19·7	25·4	15·6	0·68
Ore Stocks ... ..	1,068	18·0	20·6	11·5	1·23
Total Ore Reserves ...	4,127,247	19·7	25·4	15·6	0·68

Included in these reserves are approximately 37,000 tons of copper ore.

A small indigenous lead industry existed in Mawson, one of the minor States in the Myelat division of the Southern Shan States, from the fourteenth century until it was extinguished on the annexation of Upper Burma in 1886. Several more or less parallel ore-bearing zones occur in the local Plateau limestone and older rocks of Ordovician age which are traceable by means of old workings and scattered slag heaps. The Shan miners obtained the lead ores mainly from clay-filled cracks and fissures in the limestones, but extensive modern exploration has up to the present only succeeded in locating two small orebodies. One of these has been developed in the Bawzaing mine of the Shan States Silver Lead Corporation Ltd., where the probable ore reserves at the end of 1929 were stated to be 188,000 tons, containing 10 per cent of lead and 13 oz. of silver. The mine is closed at present. For the five years ending 1928, a total of 25,440 tons of lead ore and slags, valued at £27,940, were produced in the Southern Shan States, compared with 434 tons for the previous period.

## ZINC

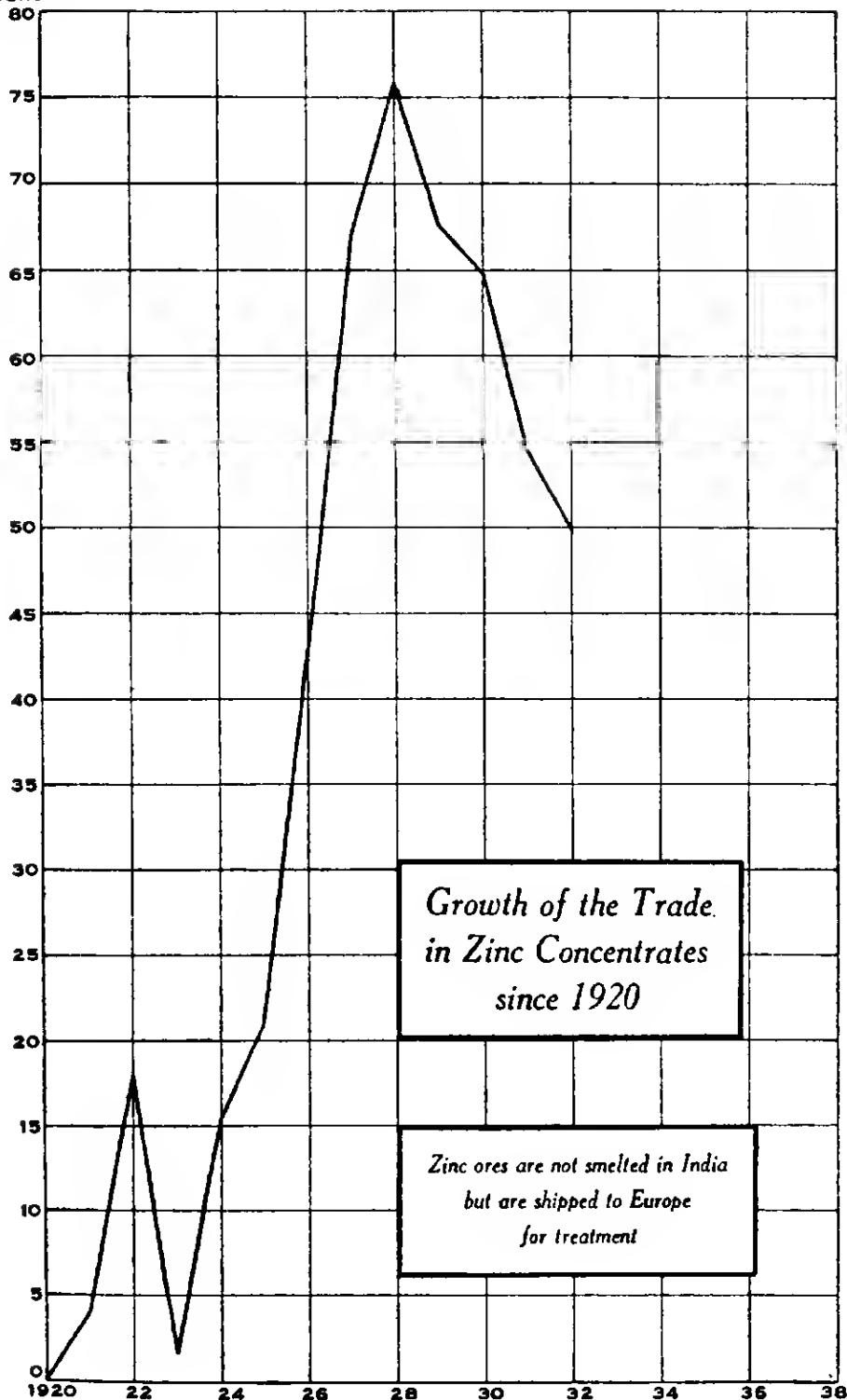
Ancient zinc mines, reputed to have been discovered in the fourteenth century and to have been closed during the great famine of 1812-13, exist near Zawar, Udaipur State, Rajputana. The principal workings, according to A. M. Heron, stretch for about three-quarters of a mile and form a vast open-cast, averaging 80 feet in width and 40 feet in depth, with irregular, cavernous excavations of unknown depth in its bottom. They are in brecciated limestone of Aravalli age, and the ore minerals are believed to have been calamine, the carbonate of zinc, and argentiferous galena. No trace of the zinc-bearing mineral appears to have actually been found, but the local ferruginous quartz and the clinker which still fills the old pots, from which the ore was distilled, contain varying quantities of zinc and lead.

The Burma Corporation Ltd. produces large quantities of zinc concentrates from its milling plant at Nam Tu. It has been stated under LEAD that the ores of the Bawdwin mine are intimate intergrowths of argentiferous galena and zinc blende with small quantities of chalcopyrite, and the 4,441,062 tons of ore which had been extracted up to 30 June 1932, contained on an average 14.3 per cent of metallic zinc. The reserves of ore still in the mine, which amount to more than 4,100,000 tons, and have been continuously added to as extraction has taken place, are estimated to contain 15.6 per cent of zinc. Regarding the disposition of the zinc blende in the Chinaman orebody, A. Calhoun, the manager of the mine, has stated: 'Taken as a whole, the southern end predominates in zinc-lead ore; the middle in more equal quantities of both; and in the northern end the zinc is partly replaced by copper. In practically all sections the ore along the hanging wall is the highest grade, with the lead predominating over the zinc, but towards the centre, or the foot wall, the zinc contents increase until, in many sections, the zinc predominates.'

In the following table the total quantities of zinc concentrates produced or exported by the Burma Corporation Ltd. are arranged in periods of five years.

THOUSAND

TONS



*Growth of the Trade  
in Zinc Concentrates  
since 1920*

*Zinc ores are not smelted in India  
but are shipped to Europe  
for treatment*

Graph 8

TABLE XI

## ZINC CONCENTRATES, PRODUCED OR EXPORTED

PERIOD	TOTAL TONNAGE	STERLING VALUE
1914-18 <sup>1</sup> ...	11,974	27,274
1919-23 <sup>2</sup> ...	24,198	122,435
1924-28 <sup>3</sup> ...	206,702	1,881,727
1929-33 <sup>3</sup> ...	273,426	1,072,523
<b>Total ...</b>	<b>516,300</b>	<b>£ 3,103,959</b>

The average composition of the concentrates shipped in 1932 was 9.02 oz. silver, 6.01 per cent lead, 51.66 per cent zinc.

The best year was in 1928 when 64,122 tons were produced, valued at £559,412. Since that time the tonnage has fallen to 51,455 in 1931. This reduction is a result of the restricted amount of the ore treated in the mill, the reason for which has been explained in the case of lead. It was stated by the Burma Corporation in January, 1933, that the production of zinc concentrates was unprofitable at the low ruling prices of spelter and was continued only because of contractual obligations and the larger spread it afforded for transport and fixed charges.

The zinc concentrates are shipped almost entirely to Belgium, though Germany has also taken smaller quantities in the past. A proposal to smelt Burmese zinc concentrates at Jamshedpur, near the works of the Tata Iron & Steel Co. Ltd., was abandoned some years ago. A later one to extract metallic zinc by the hydro-electric process in the Toungoo district of Burma, by means of power derived from the Yonzalin river, has shared the same fate. As long as the world price of spelter remains at an uneconomic level, the reconsideration of such schemes is of doubtful utility.

India consumes large quantities of zinc, not only in the form of spelter, but in brass and other alloys and in galvanized sheets—some of which are made in the country—in pigments and in various salts. The imports of zinc alone rose from 5,369 tons, valued at Rs. 27,39,234, in 1924, to 9,376 tons, valued at Rs. 36,24,114, in 1928, and for the five fiscal years ending 1932-33 were 11,045 tons, valued at Rs. 32,58,900 as an annual average.

<sup>1</sup> Three years only. No exports in 1917 and 1918.

<sup>2</sup> Exports.      <sup>3</sup> Production.



## TIN

The earliest allusion to the occurrence of tin in Burma was made by Ralph Fitch in 1599, who remarked that on his journey from Pegu to Malacca he passed by 'many of the ports of Pegu, as Martauan, the Iland of Taui (Tavoy), from whence commeth great store of tinne, which serueth all India'. The cassiterite deposits of Burma, which furnish the whole of India's tin production, have indeed been worked from a remote antiquity, especially in the Lower Tenasserim division. The granitic mountain ranges of Lower Burma are the northern continuation of the same rocks which have yielded the rich tin ore deposits of Malaya and Western Siam. The region in which the Burmese ore occurs corresponds with that described in the case of WOLFRAM, for the ores of tungsten and tin are most intimately associated and of identical origin.

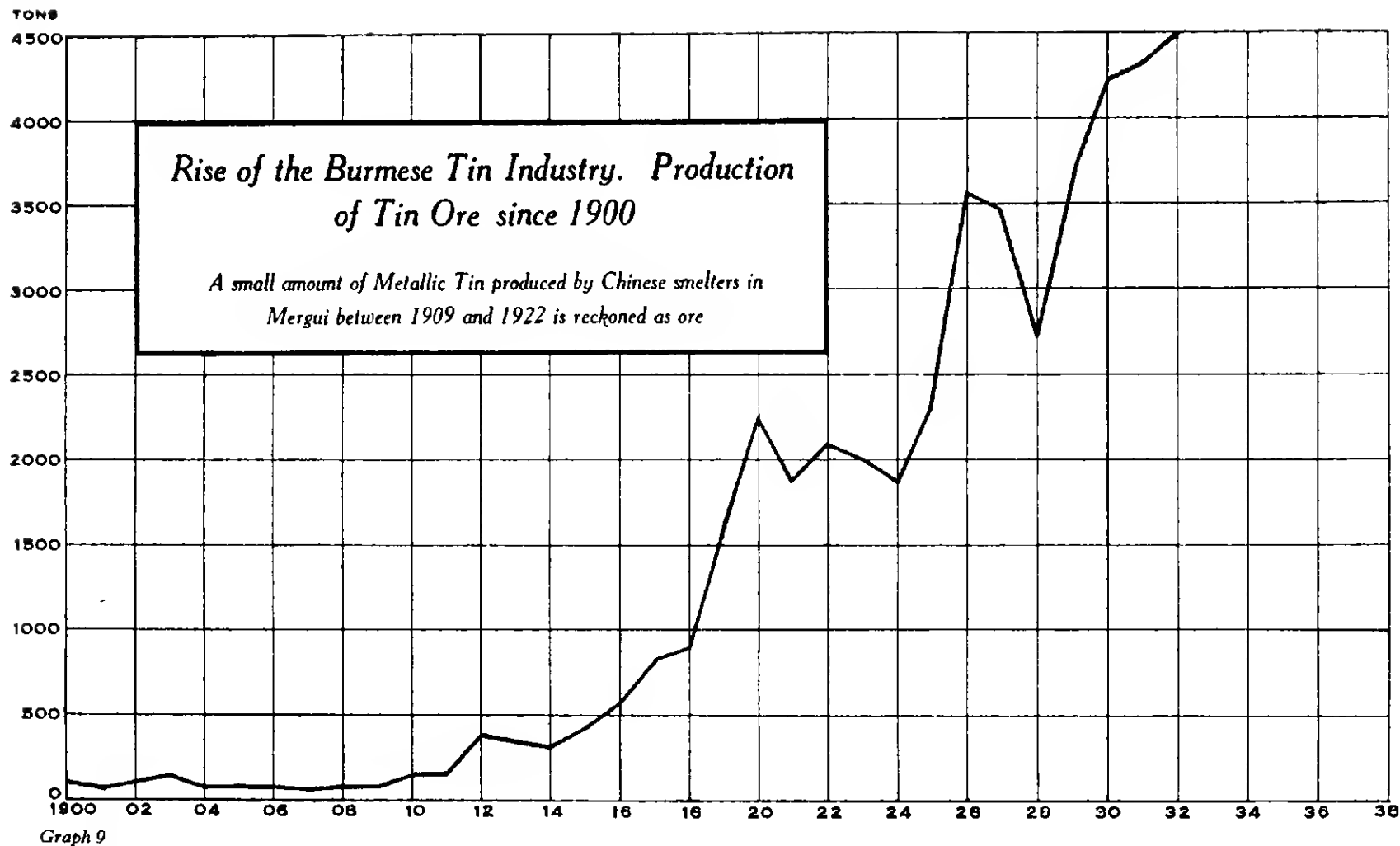
The tin and wolfram-bearing localities of the Mergui district lie in the Palaw and Palauk, the Mergui and Tenasserim and the Bokpyin and Victoria Point townships, of the north, central and southern portions, respectively. The tin mines are situated principally on the mainland, in two parallel mineralized zones, but another belt crosses Lampi and adjoining islands in the Mergui archipelago. The ore zones are more or less parallel to, and closely related to, the granitic intrusions, at or near their junctions with the sedimentary rocks of the Mergui series. The tin ore occurs as a constituent of decomposed granite and greisen, associated with tourmaline and muscovite; in quartz veins up to ten feet thick with wolfram and one or more members of the sulphide suite of minerals; and in narrow quartz veins and stringers forming stockworks in the Mergui series. Surface ore deposits of eluvial and alluvial origin are also common, and while wolfram and cassiterite occur in the former, the tin ore is found alone in the latter, as it is resistant to the process of disintegration and decay which remove the wolfram before it reaches the true water-sorted alluvials. Important centres are Maliwun, Bokpyin, Karathuri, Yengan, Manaron and elsewhere. All the known occurrences have been described by the late Rao Bahadur Setu Rama Rao, who also listed the more promising areas which have yet to be closely prospected. Tin ore used to be smelted by Chinese methods at Inner Bokpyin, Karathuri, Hangapru, Palaw and other places. Tin dredging is carried on by the Tavoy Tin Dredging Co. Ltd. at Theindaw and by Thabawleik Tin Dredging Ltd. at Thabawleik, both places being in

carries on sluicing operations in the rainy season and lode-mining during the remainder of the year. Amongst its leases is the well-known Hermyingyi mine.

The Anglo-Burma Tin Co. Ltd. undertakes hydraulic mining operations at Heinda and Onzinchaung, with four sets of monitors, hydraulic elevators and gravel pumps. The total reserves of the two areas are stated to be over 11,000,000 cubic yards. The Kanbawk (Burma) Wolfram Mines Ltd. has two dredges and a sluicing plant in operation at Kanbawk. In addition to these and other well-equipped properties, there are in Tavoy many areas which are still worked by ancestral Chinese methods. It may be confidently anticipated that once the prevailing depression is ended the output of tin ore from the Tavoy district will be greatly increased. Between the years 1898 and 1932 the production of the district was 23,312 tons, valued at £2,242,523. The maximum annual output was reached in 1932, when 2,349.6 tons were recorded, valued at £179,686. During the years 1912 and 1913, 128 tons of metallic tin were produced, valued at £16,245.

Small quantities of tin ore are also won in the Amherst and Thaton districts, the totals recorded from 1916 until the end of 1932 being 351 and 341 tons, valued at £37,246 and £30,036, respectively. The geological surveys of these districts have not been completed, but metamorphic aureoles are known to exist around the intrusions of the local granites, which belong to the same period of eruption as those in Tavoy and Mergui further south, carrying tourmaline and veins of tourmaline micropegmatite which in places bear quartz stringers with cassiterite. Lateritic talus deposits containing cassiterite have been sporadically worked at Thetkaw, while a pegmatite containing the mineral exists near Kunhnitkway, both localities being in the Amherst district.

The output of the Southern Shan States is derived entirely from the important Mawchi mine in the Bawlake State of Karenni, which is also a large producer of wolfram. In Mawchi hill there are at least ten important veins, varying from  $2\frac{1}{2}$  to 5 feet in thickness, in granite capped with limestone and flanked with slate, and carrying cassiterite, wolfram, arsenopyrite, pyrite, chalcopyrite and tourmaline. Two main cross cut adits have been driven, a concentration mill and separating plant erected, and a hydro-electric installation has been set up. The proved, and partially proved, ore reserves at the end of 1934 amounted to 154,148 tons, containing 3.5 per cent of tin and wolfram.



Graph 9

Promising finds have recently been made on another area in the same neighbourhood. The total recorded output between the years 1904 and 1932, inclusive, has been 8,797 tons, valued at £877,628.

Cassiterite has been found in four localities in the Archæan rocks of the Hazaribagh district, Bihar and Orissa. At Simratari it occurs in lenticles of granite enclosed in mica schist; near Pihira, in a dyke of lepidolite granite, and at Chappatand in a granulite. All these places lie in the mica belt around Gawan. A thin layer of cassiterite-bearing granulite, in a much thicker band of microcline granulite, at Nurunga, near Parasnath, has attracted the attention of miners from 1867 onwards, but the amount of tin ore which it has yielded is quite insignificant. Indeed, all these occurrences in India proper appear to be of more scientific interest than practical importance.

In the early years of the present century, the annual imports of tin averaged about 1,500 tons per annum. For the five years ending 1928, the annual average was 2,716 tons, valued at Rs. 95,35,073, while the actual consumption within the country itself was 2,537 tons. The corresponding figures for the quinquennial period ending 1932-33 were: imports 2,562 tons, valued at Rs. 60,54,158, and a consumption of 2,488 tons, annually. The Burmese production of ore is now well ahead of India's requirements of metal, and the question arises whether it would not be more profitable to smelt the ore within the Indian Empire, instead of exporting it to the Straits Settlements and elsewhere, as is done at present, and then re-importing the finished metal.

The large tin dredging and mining companies operating in Burma are well equipped to deal with the situation when the statistical position of the metal and an improvement in trade generally create a renewed demand for tin, and when that time arrives a rapid expansion in output is anticipated. The potentialities of the Tenasserim division of Lower Burma as a tin-producing region are by no means exhausted and there are large tracts which up to the present time have not received the detailed attention which they merit from prospectors, a consequence of the humid and malarious climate, the dense forest, the scarcity of good rock exposures and the almost uninhabited character of the outlying areas. The junctions of the granite and the sedimentary rocks in which the mineralized zones occur are now well known, thanks to the work of the Geological Survey of India, and both these and the surface deposits derived from them will doubtless be more thoroughly investigated in the future.

## CHAPTER IV

### IRON, MANGANESE, FERRO-MANGANESE, NICKEL AND COBALT

#### IRON

THE approximate time of the commencement of iron manufacture in India is unknown, but the rusted implements of the prehistoric tombs may well date from 2,000 B.C. At the time of Alexander's invasion (326 B.C.), the armed nations of Northern India were as familiar with iron and steel as the Greeks themselves. The famous pillar at the Kutb, near Delhi, is of solid wrought iron of an excellent type, 23 feet 8 inches in length,  $16\frac{1}{2}$  inches in diameter at the base and 12 inches just below the capital. It weighs over six tons and bears the epitaph, in Sanskrit, of King Chandragupta II, composed in or about A.D. 415. The manufacture of 'wootz', an Indian steel, anticipated the principle of the cementation process by many centuries, and this material was probably exported to western lands from before the Christian era, to be worked into the 'Damascus' swords of medieval times. Until it practically succumbed, in comparatively recent years, before the competition of imported metal, the indigenous iron industry was both widespread and prosperous and there is hardly a district from the extreme south to the Himalayas or from the Federated Shan States to Baluchistan, with the exception of the great alluvial plains, in which ancient iron slags have not been found. It does not follow however, that ores suitable either in quality or quantity for the needs of a modern blast furnace plant occur in all these places.

Failure attended every early attempt to graft European methods on to the native processes and to smelt iron ores on a large scale in India. In 1830, the Indian Steel, Iron & Chrome Co. was established by J. M. Heath with works at Porto Novo in South Arcot district, Madras, where ores from the Salem district were smelted. These works were subsequently carried on by the Porto Novo Steel & Iron Co., and the East Indian Iron Co., additional furnaces being

erected at Tiruvannamalai in North Arcot, and Beypur in Malabar in 1833, and at Palampatti in Salem district in 1853. Pig iron from the Porto Novo works was shipped to Sheffield steel makers, and a large quantity of it was used in the construction of the Britannia tubular and Menai bridges. These concerns never declared a dividend, steadily lost their funds and closed down about 1867.

### BENGAL

In Bengal the story begins with the grant by the East India Company to Messrs Farquhar & Motte, in 1778, of an exclusive right to manufacture iron within the Company's territories, a privilege which they enjoyed in the Birbhum district, in all probability using native methods, until they relinquished it in 1795. Experiments by Jessop & Co. with Burdwan ore in 1839 were inconclusive. In 1855 Messrs Mackay & Co. started on a small scale at Mahomed Bazaar, also in the Birbhum district, and their desultory operations were abandoned in 1875 after final experiments by Messrs Burn & Co. had proved them unprofitable. In the meantime the Kumaun Iron Works Co. Ltd. had been formed in 1862, amalgamating plants which had been erected at Dechauri and at Khurpa Tal, in the Naini Tal district of the United Provinces, in 1857. After many vicissitudes this enterprise failed as the others had done. Yet another attempt, made in 1862, at Barwai, in Indore State, Central India, under the direction of a Swedish metallurgist, met with no better success. In all these undertakings charcoal was the fuel used, or proposed, and it was not until 1875 that advantage was taken of coke made from Indian coal. In that year a private company erected two furnaces at Kulti, near Barakar, on the Raniganj coalfield, each capable of producing 20 tons of iron per day, but owing to insufficiency of capital it failed in 1879, after producing 12,700 tons of pig iron. In 1882 the plant was taken over by the Government and one furnace was restarted in 1884, operations so continuing until 1889, when the works were resold to the Bengal Iron & Steel Co. Ltd., the predecessors of the Bengal Iron Co. Ltd. (registered in 1919) of today. The plant was entirely remodelled and the Company soon established modern iron smelting in the Indian Empire on permanent foundations, though a steel plant which was erected in 1903 was closed down in 1905. Later developments include the formation of the Tata Iron & Steel Co. Ltd., the two original furnaces of which

were 'blown in' in 1911 and 1912, at Jamshedpur, 154 miles west of Calcutta; the inauguration of the Indian Iron & Steel Co.'s furnaces at Burnpore, near Asansol, on the Raniganj coalfield in 1922; and the commencement of the Mysore Government's charcoal iron furnace, at Bhadravati, near Shimoga, in the following year.

#### BIHAR AND ORISSA

At the commencement of the present century the annual production of iron ore in India averaged about 65,000 tons per annum. Today it is nearly 2,000,000 tons per annum, and of the total 24,005,002 tons raised in the 32 years concerned, no less than 22,128,699 tons, or over 92 per cent, came from Bihar and Orissa; indeed, in more recent years the percentage of ore drawn from this province alone has been over 97 per cent. Table XIII (page 120), shows the distribution of this and the remaining production. Taking the Bihar and Orissa output alone, Mayurbhanj, where mining commenced in 1911, has contributed 55½ per cent to the total, Singhbhum (1904) 41 per cent, and Keonjhar (1927) over 3 per cent.

P. N. Bose discovered the Mayurbhanj deposits in 1904, while R. Saubolle, a prospector of Martin & Co., Calcutta, found those of Pansira Buru and Buda Buru in Singhbhum in 1907, the ores worked earlier in Singhbhum being magnetites from ultrabasic magnesian rocks of the Kalimati neighbourhood. Subsequent exploration by various geologists led to the realization of the fact that in parts of Singhbhum district and in the adjoining States of Keonjhar, Bonai and Mayurbhanj, a region lying some 150 to 200 miles west of Calcutta, there exists one of the major iron ore fields of the world, in which enormous tonnages of rich ore are readily available. It usually occurs at or near the tops of hills, and the most important range runs from near Rontha in Bonai State in a north-north-easterly direction, rising 1,500 feet above the surrounding country, for about 30 miles, while hæmatite, averaging over 60 per cent of iron, occurs along practically the whole length, with a few negligible breaks. Smaller ranges also contain good ore and follow a direction roughly parallel to the main one. In 1934, H. C. Jones, from whose reports these details are summarized, estimated the minimum quantities of ore then known and averaging not less than 60 per cent iron, as follows:

					Tons
Singhbhum District	...	...	...	...	1,047,000,000
Bonai State	...	...	...	...	648,000,000
Keonjhar State	...	...	...	...	988,000,000
Mayurbhanj State	...	...	...	...	18,000,000
Total					2,701,000,000

The estimate for Mayurbhanj had not been verified, while a separate estimate by Dr M. S. Krishnan gives the total for Keonjhar State as 1,483,250,000 tons. Mining operations carried out by various companies show that the solid hæmatite often gives place to an unconsolidated, powdery variety at depths of from 80 to 100 feet below the surface. The iron ore series consists of conglomerates, purple sandstones and limestone, overlain by ferruginous shales and banded hæmatite quartzites with the iron orebodies, followed in their turn by another thick, shaly group with epidiorites and ash beds. The whole series is of Archæan age and the prevailing official view is that it forms the uppermost of the two unconformable groups into which the Dharwarian rocks of Singhbhum have been divided. The orebodies have been derived chiefly from the hæmatite quartzites by local enrichment, as a result of the leaching of silica and, to a lesser extent, the introduction of iron oxide. Like the ancient iron ores of some other countries they are believed by H. C. Jones to have been marine chemical sediments originally.

J. A. Dunn (1935) divides the Iron Ore System as follows:

5. Dalma series of volcanic flows.
4. Tuffs, flows, shales, phyllites and mica schists, quartzites and conglomerates.
3. Shales, phyllites and mica schists.
2. Limestones.
1. Sandstone-conglomerates.

The iron ores and associated banded hæmatite quartzites occur in Zone 4. Dunn rejects the theory of the sedimentary origin of the latter and states that they were formed by the secondary silicification of material now represented by ferruginous, chloritic or carbon shales or phyllites, many of which were tuffs in the first instance. He thinks that this silicification was in part contemporaneous with the deposition of the beds themselves and resulted from thermal activities which accompanied the formation of the volcanic series. The iron, according to his views, was derived partly from the oxidation of the tuffs and flows *in situ* and partly represents a wash from the



latter. Later solutions are held to have rearranged the ferruginous contents with the production of the massive iron ores.

The hæmatites vary much in their physical qualities, and massive, laminated, micaceous, powdery, lateritic and brecciated kinds occur. The iron content is usually about 64 per cent, phosphorus ranges normally from 0.03 to 0.08, but may be as high as 0.15 per cent. Sulphur is usually below 0.03. High iron percentages, low sulphur and titanium contents and variable phosphorus are the chief characteristics of these ores.

*Singhbhum and Keonjhar.* The Bengal Iron Co. Ltd. exploits the deposits of Pansira Buru and Buda Buru, in the Kolhan estate, Singhbhum, 12 and 8 miles respectively south-east of Manharpur station, on the Bengal-Nagpur Railway, to which they were joined by a light railway about 1911. The total quantity of ore at Pansira Buru has been estimated at nearly 10 million tons and at Buda Buru at 145 million tons. It is a high grade hæmatite with an average composition as follows:

<i>per cent</i>			<i>per cent</i>		
Iron	...	64.0	Magnesia	...	0.18
Silica	...	2.10	Manganese Oxide	...	0.05
Lime	...	0.15	Sulphur	...	0.002
Alumina	...	1.25	Phosphorus	...	0.05

The mines of the Indian Iron & Steel Co. Ltd. are at Gua, the termination of a branch line of the Bengal-Nagpur Railway, and also in the Kolhan estate. Dispatches from this mine commenced with the completion of the railway in 1923.

The United Steel Corporation of Asia Ltd., since 1925, has quarried the ores of the Bagia Buru ridge which runs parallel to the Bara Jamda-Barabil branch line of the Bengal-Nagpur Railway. These workings are in the Keonjhar State and yield hæmatite containing 58 to 60 per cent of iron. The Corporation having at present no plant of its own sells its iron ore to another smelter. Manganiferous iron ore is also obtained during manganese ore mining operations in the same neighbourhood. It contains between 30 and 35 per cent of manganese and about 20 per cent of iron in the form of limonite, and is also sold to iron manufacturers in India.

The Noamundi mine of the Tata Iron & Steel Co. Ltd. is also in the Kolhan estate of Singhbhum, though the orebodies actually extend into Keonjhar. It is connected with the Amda-Gua extension of the

Bengal-Nagpur Railway. Discovered by Saubolle and C. R. N. Aiyengar, independently, in 1917, it consists chiefly of two parallel ridges, each about  $2\frac{1}{2}$  miles long and half a mile wide at the north, becoming much wider to the south, and has been described in detail by F. G. Percival (1931). He divides its ores into two grades, the first of which includes the massive and laminated hæmatites as well as the lateritic ones, while the second embraces the powdery and soft, shaly ores. The reserves of the former are estimated at 140 million tons and of the latter at 88 million tons. Dispatches commenced in 1926, while the average composition of the ore mined in 1930, based on the daily assays of each waggonload was: iron 63.09 per cent, silica 2.94 per cent, and alumina 3.34 per cent. The soft and powdery ores, as is the case too with those of other parts of the field, are not of immediate utility, for though they are rich in iron and could be sintered at a cost of about Rs. 3 per ton and thus turned into a form suitable for the blast furnace, so long as hard ore is available they are not likely to be used.

*Mayurbhanj State.* Over twelve deposits of high-grade iron ore occur in the more accessible parts of Mayurbhanj State, and three of them, Gorumahisani, Sulaipat (Okampad) and Badampahar have been opened up by the Tata Company. They are all joined to the Bengal-Nagpur Railway by a branch line about 56 miles in length. The ores are of the same type as those of Singhbhum and interbedded with them are hæmatite quartzites and shales. Gorumahisani is a hill mass with three peaks, the highest of which rises 3,000 feet above sea level. Estimated to contain 9,800,000 tons of ore by E. Curnow in 1914-15, later discoveries of laminated ore have increased this figure by two or three million additional tons, though probably half of the total has been extracted. The average iron content of the dispatches (which started in 1914) up to the end of 1928, was about 64 per cent. The following analyses have been quoted by Jones.

#### ANALYSES OF GORUMAHISANI ORE

TYPE	IRON	PHOSPHORUS	SULPHUR	SILICA	NUMBER OF SAMPLES
'Float' Ore <sup>1</sup>	61.46	0.048	0.036	3.34	20
'Solid' Ore	64.33	0.075	0.021	1.64	10

<sup>1</sup> Up to 1928 the whole of the ore won was 'float' material.

Okampad and Sulaipat (2,535 feet) are prominent peaks, a mile apart and some 12 miles south-south-west of Gorumahisani. The railway reached the neighbourhood in 1922 and a tram line connects the mine with it. The main orebody, associated again with banded hæmatite quartzites, lies at the crest of the hill and, with an outlier, was estimated by Curnow to contain some 2,270,000 tons. The 'float' ore is very rich and about 936,000 tons of it were available. To these reserves must be added the contents of certain ore bands discovered later, *in situ*, on removal of the 'float' ore.

The Badampahar deposit occupies the 2,706-foot peak of the same name in the Sulaipat-Badampahar range, 8½ miles to the south-west of the Sulaipat mine. Its reserves, according to Jones, were about seven million tons in 1928. A small isolated mass of magnetite exists, but the bulk of the ore is hæmatite, which, while not so rich as that from Gorumahisani or Sulaipat, is highly valued by the smelters on account of its more porous character. As dispatched, the bulk samples average from 57 to 58 per cent iron, while a representative sample quoted by Jones has the following composition:

	per cent		per cent
Iron ...	57.60	Alumina ...	5.02
Manganese ...	0.52	Phosphorus ...	0.074
Silica ...	5.60		

Both the Badampahar and Sulaipat mines commenced work in 1922.

The geological map of Bihar and Orissa (Map V) is a compilation from the works of V. Ball, J. M. Maclaren, L. L. Fermor and others and is reproduced with permission from an article on the 'Iron and Steel Industry of India', by the author, in the *Mining Magazine* for June and July, 1921. It shows the relative positions of the coal and iron ore fields. The smaller map of India (Map VI), from the same source, illustrates the approximate locations of the chief mineral deposits which are of interest to the iron and steel industry.

#### CENTRAL PROVINCES

Beyond furnishing a few hundred tons yearly to the small native smelter, the iron ore deposits of the Central Provinces are not systematically worked at present, though they have been drawn upon as, for example, in 1923 and 1924, when for various accidental

reasons the mines of some of the iron companies operating in Singhbhum were unable to furnish regular supplies for their furnaces.

In the Chanda district at least ten separate deposits, some of them of large size, have been located, forming well marked beds of hæmatite, sometimes with magnetite, associated with banded hæmatite quartzites of Dharwarian age. The two best known are at Lohara, described by Hughes in 1873 and by Dutta in 1910, and Pipalgaon (Hughes, 1873). The former outcrops in a hill nearly half a mile long, 200 yards wide and 120 feet high, and has been traced for a further  $2\frac{1}{2}$  miles. 'The view presented by such a mass of almost pure specular iron,' wrote Hughes, 'it does not fall to the lot of many men to see surpassed and those who possess the opportunity of visiting this place ought to do so and carry away with them the remembrance of having looked upon one of the marvels of the Indian mineral world.' The Pipalgaon deposit he described as 'an excessively fine mass of red hæmatite, resembling that which occurs at Lohara if not having the same composition'. The Lohara deposit is a leased reserve of the Tata Company. The average ore is stated to contain 61 to 67 per cent of iron, 1.5 to 11 per cent of silica, 0.012 per cent of sulphur and 0.005 per cent of phosphorus.

*Drug District.* The valuable ores of the Drug district were briefly described by Bose in 1887, in his account of the indigenous industry of what was at that time the western part of the Raipur district, and he noted that the richest and most extensive deposits occurred in the Dalli-Lohara zamindari. This region was investigated by C. M. Weld for the Tata Company in 1914. The iron ores resist the action of denudation and rise in hillocks above the level of the surrounding country. The ridge, which includes the Dalli and Rajhara hills, extends for 20 miles and attains heights of 400 feet above the plain around. The ores are associated with phyllites and are often of the Dharwarian quartz-iron ore schist type. The purer varieties form lenticular bodies at two horizons; those in the lower band being from 2,000 to 3,000 feet in length and 100 feet or so in thickness, while the others in the upper hand are comparatively smaller. The mass of hæmatite which forms the crest of Rajhara hill was proved by core boring to contain  $7\frac{1}{2}$  million tons with about 67.5 per cent of iron and a phosphorus content just below the Bessemer limit. Much larger quantities probably exist beyond the depths reached by boring.

## ANALYSES OF RAJHARA IRON ORES

TYPE	IRON	PHOS- PHORUS	SULPHUR	SILICA	MANGANESE	NUMBER OF SAMPLES
Surface Samples ...	66.35	0.058	0.108	1.44	0.151	64
Cores ...	68.56	0.064	0.071	0.71	0.175	

Similar iron ores are known to have a very considerable extension into the Bastar State to the south, where indeed Bose noted two rich and extensive deposits in the Antagar tahsil in 1898. The deposits generally are believed by C. P. Perrin to carry a tonnage of from 20 to 30 times that now reasonably accurately known.

P. Sampat Iyengar (1933) is inclined to correlate the Chilpi Ghat Series with which these ores are associated, as well as the unmetamorphosed shales and phyllites of Singhbhum, with the post-Dharwar schists of Mysore, a series of phyllites, sandstones and calcareous or ferruginous or mangiferous sedimentary beds. His views on their origin have been given recently in the following words: 'The large iron orebodies, hæmatite and limonite masses and the micaceous hæmatite schists in Bihar and Orissa (South Singhbhum, Bonai, etc.), and in the Central Provinces are considered to be alterations of ferruginous shales and occasionally of hæmatite quartzites, with the local enrichment of ores largely by the leaching out of silica from the shales and to a less extent by the introduction of iron oxide by meteoric waters.'

## MYSORE

*Bababudan Hills.* Iron ores are widely distributed in Mysore, but the only ones under exploitation are those of the Bababudan hills in the Kadur district, described by Smeeth and Iyengar. The crest of this horseshoe-shaped chain of hills is formed nearly entirely of banded quartz-iron ore rocks, largely hæmatite with some magnetite. The ores, according to Smeeth, are either desilicified portions of these rocks or metasomatic replacements of quartz and silicates resulting in the formation of rich hæmatite and limonite ores, particularly on the more gentle slopes and undulations. A few million tons containing about 64 per cent iron could probably be obtained. Of ores containing about 60 per cent iron, there are

probably 25 to 50 million tons in several large deposits, and of lower grade ores, down to 55 per cent iron, there are at least 100 million and probably several times this amount. Iyengar regards the more or less banded and porous layer of limonite and hæmatite now relied upon for the Bhadravati iron works as a deposition of iron removed in solution by meteoric waters of portions of the desilicified ferruginous quartzites. The rich ores tend to occur in widely separated patches. The small Kemmangundi patch, down to a depth of 25 feet, was estimated to contain four million tons of an average composition of iron, 57 per cent, silica 2 per cent, sulphur 0.05 per cent, and phosphorus 0.08 per cent. This and a smaller deposit in the vicinity were estimated to contain three-quarters of a million tons, with iron ranging from 61 to 62 per cent and phosphorus 0.05 per cent, and two million tons with iron between 56 and 57 per cent and phosphorus 0.09 per cent. On an area near Kalhattigiri, Smeeth estimated the presence of 83 million tons, the outer crusts of which, to a depth of 3 or 4 feet, would yield 25 million tons carrying 60 to 65 per cent iron, and the remainder from 55 to 58 per cent iron. The phosphorus is somewhat high, varying from 0.044 to 0.105 per cent.

#### OTHER DEPOSITS

Other iron ore deposits of Dharwarian age occur in Goa and Ratnagiri and in the Salem and other districts of Madras, where the common occurrence of magnetite with the hæmatite led Sir Thomas Holland to suggest that they represent a stage in the thermal metamorphism of hæmatitic quartzites. Low grade siliceous iron ores, in the form of banded hæmatite and magnetite quartzites, are, in fact, common enough in the Dharwars and similar schistose rocks in peninsular India to make newly recorded finds matters of little immediate economic concern. This also applies in the case of the ferruginous laterites which, although they have often furnished ores for the small native furnaces in times past, are not utilized by the iron master of today. The lengthy lists of the iron ore occurrences of practically every province cannot be summarized here, and the interested reader will find them in T. D. La Touche's *Annotated Index of Minerals of Economic Value*. It remains to point out that manganiferous iron ores are mined for blending purposes in the production of certain special varieties of pig iron; that the nodules of

clay ironstone found in the ironstone shales of some of the coalfields were used as a source of iron for many years by the Bengal Iron & Steel Co. Ltd.; that titaniferous iron ore is exported in large amounts from the sea beaches of the Travancore coast as a source of titanium compounds; and that residual hæmatitic and limonitic iron ores are won in the Federated Shan States for use in lead smelting operations at Nam Tu.

### THE MANUFACTURE OF IRON AND STEEL

About 1900 the average annual production of pig iron in India was approximately 35,000 tons, which came entirely from the works of the Bengal Iron & Steel Co. Ltd. For the four years ending 1932, it averaged 1,134,621 tons per annum. Of the grand total of 13,360,140 tons made during the present century, 16·8 per cent was produced by the Bengal Iron Co. Ltd., or its predecessors; 61·3 per cent by the Tata Iron & Steel Co. Ltd.; 20·6 per cent by the Indian Iron & Steel Co. Ltd.; and 1·3 per cent by the Mysore Government's iron works. The annual average production of steel, including rails made solely by the Tata concern, has risen from 63,175 tons in 1912-13 to 426,855 tons, the annual average for the four years ending 1932. Details of the growth of the industries are tabulated in Table XII (page 119). See also Graph 10 (page 118).

*The Bengal Iron Co. Ltd.* The early history of the Bengal Iron Co., Ltd., has already been briefly referred to. At present the Kulti works include five modern blast furnaces, capable of turning out 250,000 tons of pig iron per annum. Coke is made on the spot in Simon-Carves regenerative ovens, with recovery of the usual by-products. The company has always specialized in the manufacture of cast iron products, and large foundries adjoin the blast furnace plant, comprising special pipe, sleeper and general castings departments. The site on the Raniganj coalfield, 142 miles from Calcutta, was originally chosen on account of the occurrence of both coal and iron ore in the vicinity, the ironstone shales from which the latter was derived stretching east and west from the works. The use of these ores was abandoned long ago and supplies are now drawn from the Company's mines in Singhbhum. Coal is obtained from the Company's collieries on the Raniganj and Jharia fields. In normal times employment is found for some 15,000 workers.

*The Tata Iron & Steel Co. Ltd.* The works of the Tata Iron & Steel Co. Ltd., which was formed in 1907, are at Jamshedpur, adjoining Tatanagar station on the Bengal-Nagpur Railway, 154 miles west of Calcutta, about 115 miles south of the Jharia coal mines and 45 miles north of the iron orefield in Mayurbhanj. Dolomite and limestone are obtained from the Gangpur State, 110 miles to the west-south-west. The original plant consisted of two blast furnaces, with a total capacity of 400 tons of pig iron per day, which were 'blown in' in November 1911 and September 1912 respectively, and seven open-hearth steel furnaces, four of which had a capacity of 55 tons and three of 75 tons per heat. A third blast furnace (300 tons capacity) commenced work in August 1919, the fourth (500 tons) in December 1922 and the fifth (500 tons) in January 1924. About 800,000 tons of pig iron have actually been made in one year, while the remodelling and re-equipment which have taken place from time to time, have resulted, it is stated, in the three largest furnaces alone now having an annual capacity of nearly one million tons of pig iron per annum.

The manufacture of steel commenced in 1912 and has steadily increased up to an average of over 426,000 tons, in the form of ingots and rails, over the four years ending 1932. The steel plant consists of seven open-hearth, stationary furnaces with a combined capacity of 1,000 tons of ingots daily, as well as a Duplex plant of three convertors which feed three 200-ton, tilting, open-hearth furnaces with a capacity of approximately 1,500 tons daily. In the blooming mills provision is made to reduce the steel ingots into blooms and slabs of varying dimensions, which are subsequently rolled into rails, structural sections, sheet bars, tin bars, sleeper plates and wide flats; to be turned later into the very numerous steel products which this firm markets and which include rails of many descriptions, fish plates and steel sleepers; beams, joists, angles, channels and tees; plates of varying thicknesses and widths. Sheet mills with annealing furnaces, pickling and galvanizing equipment make black and galvanized sheets, in addition to the plates which are later turned into 'tin plate' by a subsidiary company. The combined finishing capacity of all the Tata mills has been recently stated to be between 600,000 and 700,000 tons of finished steel annually, while a pressed steel sleeper plant is capable of making 20,000 tons of steel sleepers annually. The Company owns its own iron and manganese ore mines, limestone and magnesite



quarries. Coke is made at the works, in modern recovery ovens of the Coppée, Koppers and Wilputte types. In May 1935 the Company ordered a new by-product coking plant of Simon-Carves design, at a cost of over £500,000. It comprises a battery of 54 compound gas-fired ovens with a maximum capacity of 1,560 tons of coal a day. The ovens will be arranged so that they may be extended later to deal with a daily throughput of 4,800 tons of coal.

*The Indian Iron & Steel Co. Ltd.* The Indian Iron & Steel Co. Ltd., registered in 1918, commenced to manufacture iron in November, 1922, at Burnpore, on the Bengal-Nagpur Railway close to its junction with the East Indian Railway, two miles west-south-west of Asansol on the Raniganj coalfield and 132 miles north-west of Calcutta. The works consist of two 500-ton, mechanically charged, modern, blast furnaces. Batteries of Simon-Carves ovens make coke at the works, while the ore is derived from the Company's mines at Gua in the Singhbhum district.

*The Mysore Iron Works.* The Mysore Government's iron works, where work was commenced in January, 1923, are at Bhadravati, 11 miles east of Shimoga, and consist of a single blast furnace with a capacity of about 60 tons of pig iron per day, together with a wood distillation plant in which the charcoal used as fuel is made and the by-products, wood alcohol, calcium acetate and wood tar are recovered. The main source of the ore supply is the Kemmangundi field in the Bababudan hills, 28 miles to the south. Limestone comes from Bhandigudda, 13½ miles to the east, while the wood is supplied by the adjoining forests.

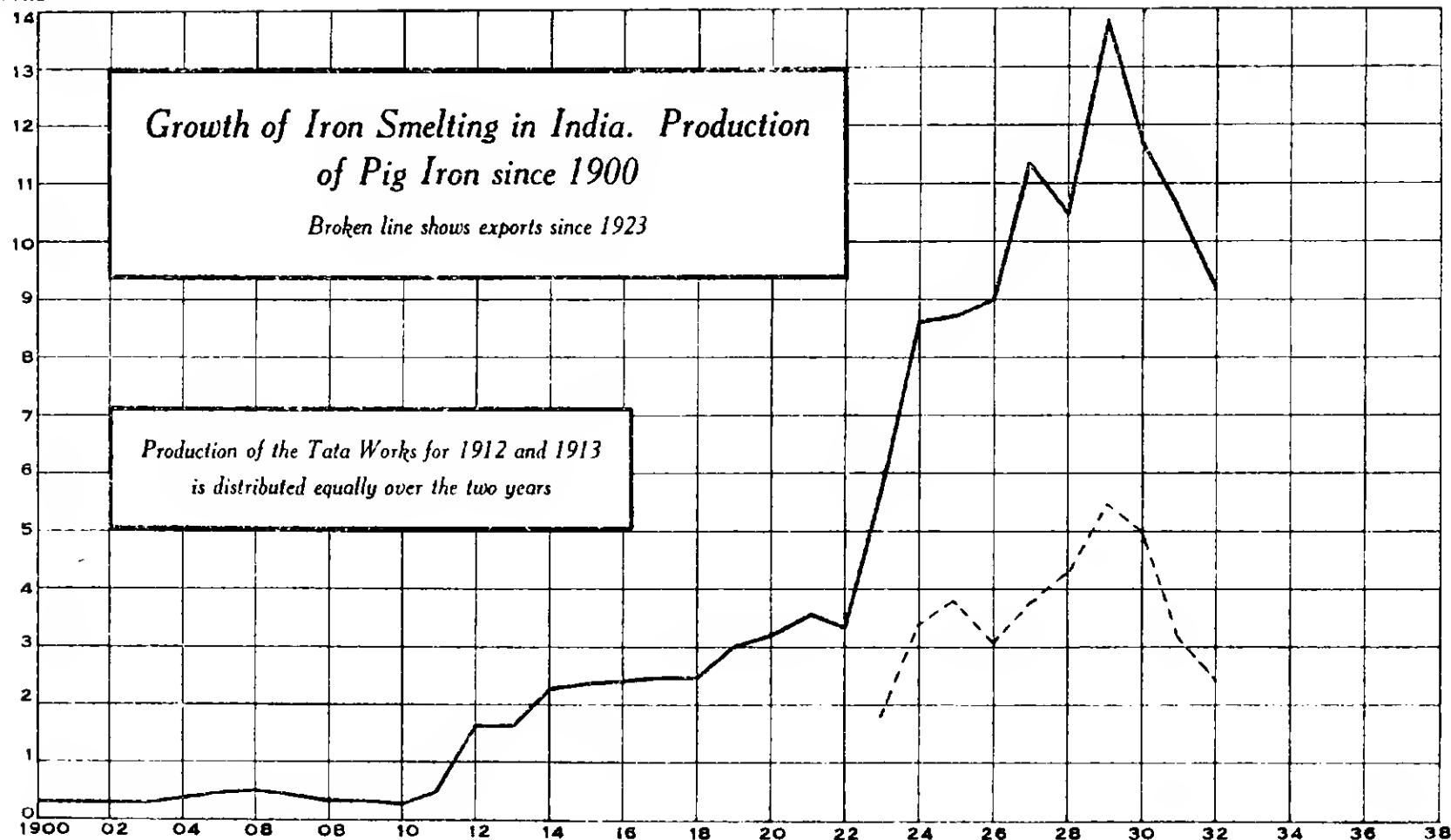
#### THE TRADE IN IRON AND STEEL

Indian imports of pig iron had fallen to 380 tons in 1931-32, and are likely to be confined in future to small quantities of special brands required for unusual purposes. In recent years India has become a large exporter of the metal. Even before the Great War, Indian-made iron had been shipped to Burma, the Straits Settlements, Ceylon, Java, Manchuria, China, Japan, Australia, New Zealand, the United States and South America. During the war, export was prohibited and the whole output of Indian steel rails was taken for use in Mesopotamia, East Africa and Palestine, a portion being shipped as far as Salonica. Shell steel was supplied to the Indian munitions works, and both the

iron-producing companies then in existence made ferro-manganese on a large scale. Post-war conditions interfered for some time with the resumption of the export trade in pig iron on its former scale, but it slowly improved. An analysis of the returns for the periods 1924-28 and 1929-32, shows that while the annual average tonnage exported in the former period amounted to 360,119 tons, it had increased to 405,160 tons for the latter, in spite of the fact that the exports in 1932, at 250,137 tons, were less than half those of the record year 1929 (548,881 tons) owing to the world depression. Of the grand total of 3,421,238 tons shipped between 1924 and 1932, 57.7 per cent went to Japan, 20.9 per cent to the United States of America, 11.2 per cent to the United Kingdom, 2.3 per cent to Germany, and 7.9 per cent to other countries. In spite of the increasing quantities of steel which are made in the country, large tonnages continue to be imported. Thus in the case of steel bars, angles and channels, ingots, blooms, billets, etc., the average annual imports for the five years ending 1928 (and the depression makes later figures unreliable as a gauge of the potential markets) totalled 227,227 tons valued at Rs. 2,64,00,149, compared with 163,143 tons, with a value of Rs. 3,87,59,033 for the previous quinquennium (1919-23). Again, in the case of articles classified in the Customs Returns as 'Iron and steel beams, sheets, pillars, rivets, etc.,' the figures for the period 1924-28 were 795,102 tons, valued at Rs. 17,17,19,344, compared with the previous similar period's 443,629 tons and Rs. 16,91,52,163. When more finished materials, such as railway plant and rolling stock, machinery and millwork, cutlery and hardware are taken into consideration, the gap between Indian production and consumption becomes very much wider still.

The future outlook for the Indian iron and steel industry is bright. The immense natural resources of the country, particularly in comparison with those of some other eastern lands, its position of easy accessibility to the markets of the Indian and Pacific oceans, the proved metallurgical skill of its iron masters and steel founders, and the commercial ability already displayed in the development of the export trade in pig iron—these, together with the great potential and growing home market for steel goods of every description, all presage expansion when world commerce returns to its normal channels.

HUNDRED  
THOUSAND  
TONS



Graph 10

TABLE XII

## PRODUCTION OF IRON, FERRO-MANGANESE AND STEEL IN INDIA, 1900-32

PERIOD	BENGAL IRON CO.		TATA IRON & STEEL CO.			INDIAN IRON & STEEL CO.	MYSORE IRON WORKS	TOTAL TONNAGE	AVERAGE ANNUAL PRODUCTION	
	Iron	Ferro-Manganese	Iron	Ferro-Manganese	Steel	Iron	Iron	Iron Only	Iron Only	Steel Only
1900-03 ...	140,000 <sup>1</sup>	...	...	...	...	...	...	140,000	35,000 <sup>2</sup>	...
1904-08 ...	209,595 <sup>1</sup>	...	...	...	...	...	...	209,595	41,919	...
1909-13 ...	241,820 <sup>1</sup>	...	231,925 <sup>3</sup>	...	63,175 <sup>4</sup>	...	...	473,745	94,749	31,587
1914-18 ...	381,579	14,371 <sup>5</sup>	835,185	5,976 <sup>7</sup>	479,930 <sup>6</sup>	...	...	1,216,764	243,353	95,986
1919-23 ...	491,473	4,731 <sup>8</sup>	1,355,333	12,225	864,280 <sup>4</sup>	77,980 <sup>9</sup>	9,732 <sup>10</sup>	1,934,518	386,903	172,856
1924-28 ...	481,218	...	2,847,641	34,306	1,593,993 <sup>6</sup>	1,430,525	87,651	4,847,035	969,407	318,798
1929-32 ...	300,009	...	2,918,349	22,938	1,707,425 <sup>6</sup>	1,247,745	72,380	4,538,483	1,134,621	426,855
Totals ...	2,245,694	19,102	8,188,433	75,445	4,708,803	2,756,250	169,763	13,360,140		

GRAND TOTAL of PIG IRON=13,360,140 tons.

Bengal Iron Co.'s	...	percentage of total pig iron	= 16·8 per cent
Tata Iron & Steel Co.'s	"	"	= 61·3 "
Indian Iron & Steel Co.'s	"	"	= 20·6 "
Mysore Iron Works'	...	"	= 1·3 "

<sup>1</sup> Production of Bengal Iron & Steel Co. Ltd.<sup>2</sup> Approximate.<sup>3</sup> Commenced December 1911.<sup>4</sup> Ingots.<sup>5</sup> In 1917 and 1918.<sup>6</sup> Steel including rails.<sup>7</sup> 1915 to 1917.<sup>8</sup> In 1919.<sup>9</sup> Commenced in November 1922. Figures for 1923 only.<sup>10</sup> Commenced in 1923.

*TABLE XIII*  
**PRODUCTION OF IRON ORE IN INDIA**

PERIOD	BIHAR AND ORISSA	BENGAL	BURMA	CENTRAL PROVINCES	MYSORE	OTHERS	TOTAL TONNAGE	TOTAL VALUE	AVERAGE ANNUAL PRODUCTION
1900-03	...	252,111	...	...	...	14,400 <sup>1</sup>	266,511	£ 38,785	66,828
1904-08	...	383,431 <sup>2</sup>	...	10,949	...	13,134	407,514	68,846	81,502
1909-13	1,282,392	95,274	59,998	13,058	...	4,564	1,455,286	147,622	291,057
1914-18	2,001,643	3,447 <sup>3</sup>	106,532	37,379	...	747	2,149,748	174,106	429,949
1919-23	3,257,233	...	200,014	35,793	16,669 <sup>4</sup>	757	3,510,466	577,958	702,093
1924-28	8,025,628	...	294,595	72,222	158,692	776	8,551,913	1,759,856	1,710,382
1929-32	7,464,719	...	88,044	3,206	107,595	...	7,663,564	1,448,123	1,915,891
Totals	22,031,615	734,263	749,183	172,607	282,956	34,378	24,005,002	4,215,296	

<sup>1</sup> Estimated.

<sup>2</sup> Of this tonnage, 286,347 tons were from Bengal and the remainder (97,084 tons) from districts which later became part of the province of Bihar and Orissa.

<sup>3</sup> Ceased in 1915.

<sup>4</sup> Started in 1923.

## MANGANESE

The world's demand for manganese ores now exceeds three million tons a year in normal times, rising and falling with the fortunes of the iron and steel industry in which over 90 per cent of the output is consumed. The world's production of steel has grown from about 13 million tons per annum in 1890 to about 118 million tons in 1929, and the annual yield of manganese ores has increased from under half a million tons to over three million tons in the same period. Employed to some extent in the manufacture of pig iron, it is chiefly used in the Bessemer and open-hearth steel making processes, in the form of alloys such as ferro-manganese, spiegeleisen and silico-manganese, in which its main purposes are to supply carbon and to remove oxygen and sulphur. These indispensable functions having been performed, most of the manganese passes into the slags. To the genius of J. M. Heath, a servant of the East India Company, who resigned his appointment to develop the iron and steel industry in South India, are due those earliest successful metallurgical experiments with manganese, which, in the words of an American authority, 'completely revolutionized the steel industry of England' and through it of the whole world. Specially prepared manganese steels, containing generally from 11 to 14 per cent of the element, are exceedingly hard and very tough. They serve for many purposes where resistance to abrasion and shock are necessary, as in the case of railway crossings and points or rock-breaking machinery. Steels containing from 20 to 25 per cent of nickel and about 5 per cent of manganese are used for electrical resistance wires, but other alloys such as the manganese bronzes contain still smaller quantities of the metal. Finally, some manganese ores have numerous applications in industry, including bromine and chlorine manufacture, the preparation of dry batteries, Leclanché cells, disinfectants (sodium and potassium permanganates), and pharmaceutical products. They are used for making brown, green and violet pigments, for colouring glass, and in glazes for bricks, tiles and pottery ware. It is worth recalling in this connexion that the amethyst owes its colour to manganese. At the same time they form valuable decolourizing agents in glass manufacture, and with linseed oil form 'driers' for paints and varnishes. In metallurgy they are employed as fluxes in the smelting of silver and copper ores.

The Indian manganese industry dates from 1891, when a syndicate

was formed to open up the Kodur deposits of the Vizagapatam district, Madras; while in 1894, the Vizianagram Mining Co. Ltd. was registered. W. King, a geologist of an earlier generation, has related how in 1885 he found psilomelane, a valuable ore of manganese, used on a large scale as road metal to the north of Vizianagram. The Central Provinces Prospecting Syndicate commenced work on the previously known Mansar deposit, in the Nagpur district, in 1899; in 1901 on the great Balaghat orebody, and in 1903 at Chikhla and Kurmura in Bhandara. In 1908 it became a limited company with about 20 mines in various parts of the Provinces. It has had a most successful career, and changed its name into the Central Provinces Manganese Ore Co. Ltd. in 1924. In 1904, the Central India Manganese Co. Ltd. was formed to continue the work of earlier concessionaires on several deposits in the Nagpur district, and in 1905 extended its operations into Bhandara. The Central Indian Mining Co. Ltd. was incorporated in 1903, with mines at Kodegaon and later at Kachi Dhana, Sitapar and Gowari Warhona in Chhindwara. Several other firms and individuals commenced work on a smaller scale in the Central Provinces between 1903 and 1906.

The first prospecting licence in Central India was granted over the Kajlidongri deposit, in Jhabua State, to Messrs Kiddle, Reeve & Co. of Bombay, in 1902. Development commenced to the south of Chaibasa, Singhbhum district, in what was then Bengal but is now Bihar and Orissa, in 1904, and was later continued by the Madhu Lal Doogar Syndicate. The Shivrajpur Syndicate was working in the Panch Mahals of Bombay in 1905, and the Bamankua Mining Syndicate in 1907. The earliest prospecting licences in Mysore were taken out in 1904, and the Mysore Manganese Co. Ltd. was registered in 1906, with rights in the Shimoga district. The Peninsular Minerals Co. of Mysore Ltd. was formed in 1906, with mines in the Tumkur and Chitaldrug districts, and the Shimoga Manganese Co. Ltd. in 1907. In addition to most of the companies mentioned the following were also recently at work.—In the *Central Provinces*: The Netra Manganese Co., The Tirody Manganese Ore Co., The Carnegie Steel Co., The Tata Iron and Steel Co., B. P. Byramjee & Co., The Nagpur Manganese Mining Syndicate, and The Bansilal Abirchand Mining Syndicate. In *Madras*: The General Sandur Mining Co. In *Mysore*: The United Steel Companies. In *Bihar and Orissa*: The New Gangpur Mining Syndicate, and Bird & Co.

## THE MANGANESE ORE TRADE

India's chief competitors in the manganese ore markets for many years were Russia and Brazil, but as early as 1908 she displaced Russia from the premier position and maintained the lead until 1912, when Russia resumed it. The Great War paralysed the Russian industry and affected the Indian one to some extent, while Brazil and the United States greatly improved theirs, though insufficiently to oust India from the first place. About this time a number of new competitors appeared, particularly Egypt and the Gold Coast. In the next decade, 1919-28, India maintained her lead and the Russian industry made a remarkable recovery, approaching the Indian output closely in 1926, while the Brazilian production fell away and the output from the Gold Coast increased. In 1929, Russia with a total tonnage of over 1,230,000 again displaced India (994,279 tons), maintaining her position through 1930 with 1,543,000 tons against India's 829,946 tons. For later years information regarding Russian production has not been made available so that it is impossible to gauge to what extent she shared in the general collapse of the market which has since taken place and which reduced the Indian output of 212,604 tons in 1932 to the level of activity of upwards of thirty years ago. 'The full magnitude of this catastrophe to the Indian manganese industry,' wrote Sir Lewis Fermor, 'is perhaps best realized from the fact that whilst the quantity of the production in 1933 (218,307 tons) was a little over one-fifth of that of the peak year of 1927 (1,129,353 tons), the value (£123,171) was less than one twenty-second part of the 1927 production (£2,703,068).'

The prosperity of the Indian manganese ore industry, apart from its ability to supply ore at competitive prices, depends entirely on the world's demand for steel. The peak year of steel production was 1929, with a total world output of 118 million tons, in which the share of the United Kingdom, India's best market, was 9,636,000 tons, and the contribution of the United States of America nearly 56½ million tons. By 1932 world production had fallen to 49,800,000 tons of which the United Kingdom was responsible for 5½ million and the United States for 13½ million tons. These figures are sufficient explanation of the exceedingly depressed condition to which manganese mining in India has been reduced. Improvement commenced however in 1933 with an increase in the world's output of steel to 67,800,000 tons, the United Kingdom increasing by 39·04



per cent to 7,300,000 tons and the United States by 77·7 per cent to over 24 million tons. In 1934 further progress was registered, the world's production increased to approximately 80,000,000 tons, to which the United Kingdom contributed 8,859,000 tons and the United States 25,450,000 tons. British steel production for the first seven months of 1935 averaged 800,643 tons per month. Such improvements in the steel trade must result in a larger demand for manganese ore in due course and have indeed already led to the reopening of the more important mines closed during the great depression in India. On the return of normal times the bulk of the trade will doubtless be competed for by the same countries as before, with the added certainty of large available supplies from the new deposits in the Cape Province of South Africa.

An encouraging feature of the Indian manganese trade is that the opening of the new port of Vizagapatam is expected to enable the demand for second grade ores to be met in so far as shipping is available. Hitherto, it is stated, such ores have been difficult to sell on account of the railway freights to Calcutta and Bombay from the Central Provinces. It has also been authoritatively stated that the world demand for second grade ore amounts to about two-thirds of the tonnage of the first grade, and it is to be hoped that India, in addition to benefiting by the increasing demand for the highest quality ore, will also participate to a considerably greater extent in this business than has been the case in the past.

Of the 16,252,000 tons of manganese ore shipped from ports in British India between the years 1895 and 1931, exactly 40 per cent went to the United Kingdom, 21·3 per cent to Belgium, 17·16 per cent to France and 15·38 per cent to the United States of America. The countries taking smaller quantities included: Holland, 2·11 per cent; Italy, 1·16 per cent; Germany, 1·39 per cent; and Japan, 0·71 per cent. Parts of the shipments to Belgium and Holland probably reached Germany. The destinations of the tonnages shipped from Portuguese India are not known.

The Central Provinces is by far the most important region, and up to the end of 1931 had accounted for 70 per cent of the total Indian production. Madras came next with 14·9 per cent, followed by Bombay (6·1), Mysore (4), Bihar and Orissa (3·9) and Central India (1·1) per cent. In the Central Provinces the leading district is Balaghat, followed by Nagpur, Bhandara and Chhindwara. Madras

ores are drawn mainly from Sandur State and Vizagapatam district, while Mysore produces chiefly from the Shimoga district. The Panch Mahals head the list for Bombay Presidency. The Central Indian ore was derived from Jhabua State, while Gangpur and Keonjhar contribute to the Bihar and Orissa total.

#### INDIAN MANGANESE ORE DEPOSITS

Sir Lewis Fermor has classified the deposits of economic importance as follows:

(a) Deposits associated with rocks of Dharwar age, the manganiferous facies of which, when containing spessartite-garnet, is known as the Gondite series. Found in:

Bihar and Orissa: *Gangpur*<sup>1</sup>

Bombay: *Narukot, Panch Mahals, Chhota Udaipur*

Central India: *Jhabua*

Central Provinces: *Balaghat, Bhandara, Chhindwara, Nagpur, Seoni*

(b) Deposits associated with a series of manganiferous intrusives known as the Kodurite series. Found in:

Madras: *Ganjam, Vizagapatam*

(c) Deposits occurring as lateritoid replacement masses on the outcrops of Dharwar rocks. Found in:

Bihar and Orissa: *Keonjhar, Singhbhum*

Bombay: *Dharwar, North Kanara, Ratnagiri*

Central Provinces: *Jubbulpore*

*Goa*

Madras: *Bellary, Sandur*

Mysore: *Chitaldrug, Kadur, Shimoga, Tumkur*

In addition to these occurrences, manganese ore has been won from the low level laterite of Goa, in Portuguese India, and the high level laterite of the Belgaum district, Bombay.

The Gondites are metamorphosed manganiferous sediments of Dharwar age, characterized by spessartite-garnet and the manganiferous pyroxene, rhodonite. As a result of profound regional metamorphism, intensified in some cases by the contact effects of later intrusives, the original sands and clays have been changed into quartzites, phyllites and mica schists, the purer manganese-bearing sediments into crystalline manganese ores and the mixtures of the

<sup>1</sup> *Italics* denote that ore has been worked for export.

THOUSAND

TONS

1200

1100

1000

900

800

700

600

500

400

300

200

100

0

1900

02

04

06

08

10

12

14

16

18

20

22

24

26

28

30

32

34

36

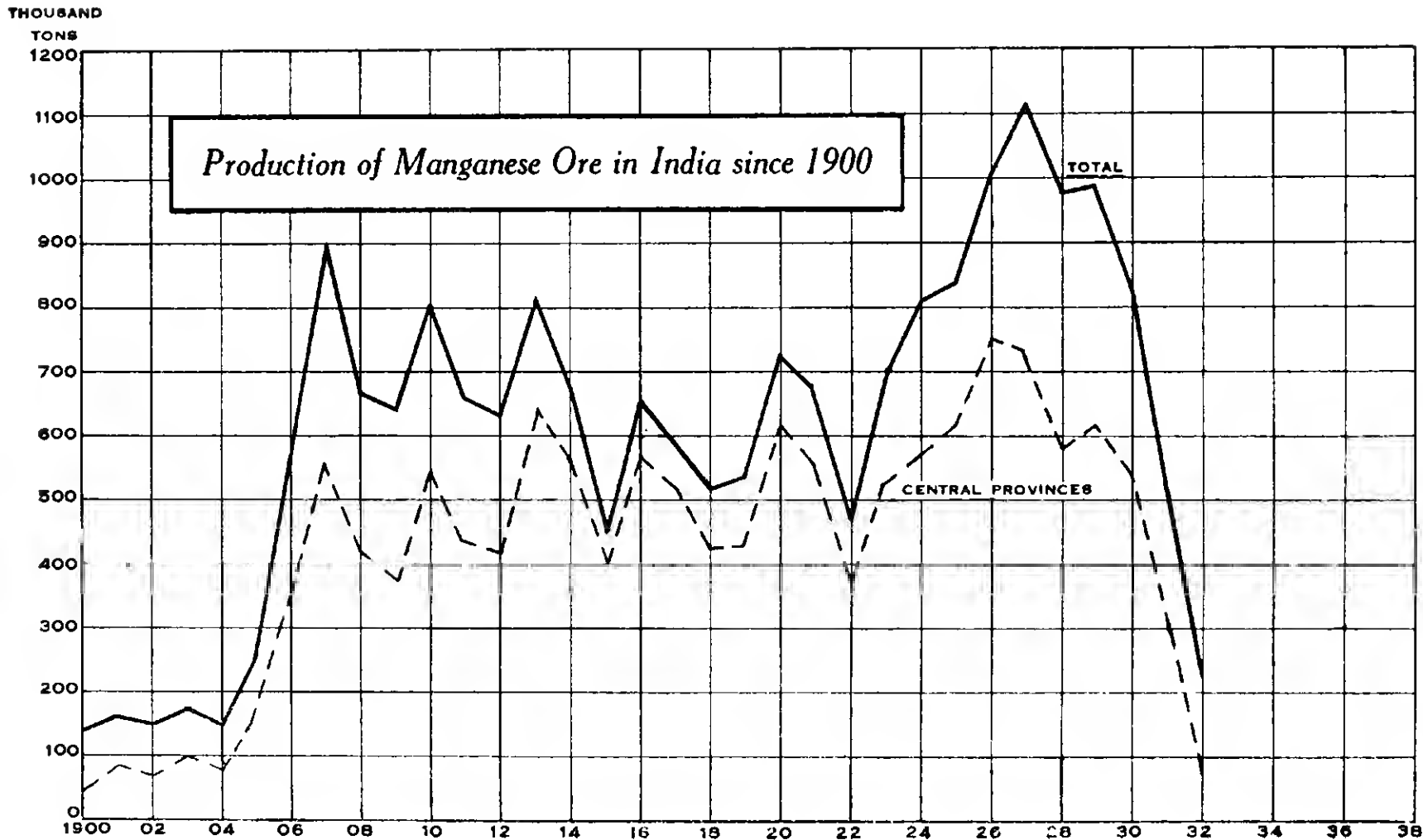
38

*Production of Manganese Ore in India since 1900*

TOTAL

CENTRAL PROVINCES

Graph 11



**TABLE XIV**  
**PRODUCTION OF MANGANESE ORES IN INDIA**

PERIOD	BIHAR AND ORISSA	BOMBAY	CENTRAL INDIA	CENTRAL PROVINCES	MADRAS	MYSORE	TOTAL TONNAGE	EXPORT VALUES (f.o.b.)	PERCENTAGE OF WORLD'S PRODUCTION
1892-98	...	...	...	...	225,346	...	225,346	£ 233,845	
1899-03	...	...	6,800 <sup>1</sup>	312,621 <sup>2</sup>	384,378	...	703,799	873,175	
1904-08	23,933 <sup>3</sup>	54,213 <sup>4</sup>	140,946	1,584,523	513,845	228,243 <sup>5</sup>	2,545,718	3,386,595	50·6(1908 only)
1909-13	160,558	178,360	42,773	2,442,424	598,468	141,401	3,563,984	4,227,025	40·7
1914-18	37,662	175,216	7,008	2,479,402	66,973	121,023	2,887,284	6,276,651	34·1
1919-23	102,267	286,475	...	2,527,011	98,910	108,513	3,123,176	9,473,413	44·1
1924-28	282,622	367,198	27,783	3,302,796	624,566	160,232	4,765,197	12,497,315	33·6
1929-32	219,638	160,304	...	1,553,877	580,704	60,150	2,574,673	3,638,242	

GRAND TOTAL, to end of 1932, 20,389,177 tons, valued at £40,606,261.

- <sup>1</sup> Production commenced in Central India in 1903.  
<sup>2</sup> " " Central Provinces in 1900.  
<sup>3</sup> " " Bengal (now Bihar and Orissa) in 1906.  
<sup>4</sup> " " Bombay in 1905.  
<sup>5</sup> " " Mysore in 1906.

two into rocks composed of manganese silicates. The latter, owing to subsequent alteration, have also formed great orebodies. These occur as lenticular masses and bands intercalated in the quartzites, schists and gneisses and often disposed along their strike. Such a line occurs in the Nagpur district, stretching from Dumri Kalan to Khandala, a distance of 12 miles, and includes the valuable deposits of Beldongri, Lohdongri, Kacharwahi and Waregaon. The orebodies frequently attain huge dimensions, thus the Balaghat deposit is  $1\frac{3}{4}$  miles long, another at Manegaon in Nagpur is  $1\frac{1}{2}$  miles long, while the band running through Jamrapani, Thirori and Ponia, in Balaghat, is exposed more or less continuously for nearly six miles. Equally impressive are the large quantities of ore yielded by single deposits and particularly by Balaghat, Thirori and Kandri, which by the end of 1928 had given 1,478,292; 1,271,223 and 1,098,595 tons respectively. The majority of the orebodies formed small hills originally and favoured exploitation by the simplest form of quarrying (see Plate V, from a photograph kindly supplied by Bird & Co. Ltd.). The most typical ore is a hard, fine-grained mixture of braunite ( $3\text{Mn}_2\text{O}_3 \cdot \text{MnSiO}_3$ ) and psilomelane, a hydrous manganese manganate, of uncertain constitution, perhaps conforming to the formula  $\text{H}_4\text{MnO}_5$ , and in which replacements by other elements always occur. Although some of these and other similar deposits have now been exploited for over thirty years, it was officially stated by the Central Provinces Manganese Ore Co. Ltd. in April 1935, that the large amounts of ore they still contain is impressive and that the question of supplies is unlikely to arise for many years to come.

The kodurites of Vizagapatam, which are associated with other Archæan crystalline rocks and particularly the khondalites, were described by their discoverer as a separate series of igneous intrusive masses, resolved by differentiation into a range of rock types from ultra-acid to ultra-basic, the typical one being the basic member composed of potash-felspar, spandite-garnet and apatite. Later, Sir Lewis Fermor suggested that they might be hybrid rocks, the result of reactions between granitic intrusions of some magnitude and manganese orebodies with manganese silicate rocks, allied perhaps to the gondites. P. Sampat Iyengar 'is inclined to simplify matters by regarding the kodurites and khondalites to be one and the same, derived from the metamorphism of arenaceous, argillaceous and manganeseiferous sediments'. In his latest pronouncement (1933), he



OPENING UP A MANGANESE ORE DEPOSIT

regards the original rock affected 'as probably the post-Dharwar manganiferous shale—a sedimentary bed'. Whatever their origin may have been, however, at some subsequent time they have been greatly changed with the production of lithomarges, manganese ores and other secondary products such as chert, ochres and wad. These ore-bodies are often very irregular, but in other cases have a well developed dip and strike. Some of them are of great size, the largest being at Garbham with a length of over 500 yards and a thickness of 167 feet at its greatest section, 100 feet of this being ore and the remainder lithomarge, wad, etc. It has yielded upwards of one million tons of ore since its opening in 1896. The Kodur deposit of this group has the distinction of being the first to be mined in India. The ores are mainly psilomelane with smaller amounts of pyrolusite (manganese dioxide,  $\text{MnO}_2$ ), braunite and manganomagnetite [ $(\text{Fe}, \text{Mn})\text{O}$ ,  $\text{Fe}_2\text{O}_3$ ] and are usually, though not always, of second and third grade, characterized by high iron and phosphorus contents and comparatively low in silica.

The lateritoid, or laterite-like deposits to which the Sandur, Mysore, and certain examples in Singhbhum and Keonjhar State (Bihar and Orissa) belong, are secondary surface replacements on Dharwar rocks. In their irregular structure they resemble laterite, whilst their radiating, botryoidal and stalactitic-like habits betray their origin. They always contain high percentages of iron, and often grade through ferruginous manganese ores and manganiferous iron ores into iron ores proper. Their manganese minerals are pyrolusite, psilomelane, wad (soft amorphous mixtures of impure manganese oxides, passing into psilomelane) and more rarely pseudo-manganite (manganite  $\text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$  passing into pyrolusite). Their iron compounds are usually limonite and earthy hæmatite. The chemical characteristics of the commercial ores are high iron, low manganese, low silica and often very low phosphorus contents, and they are usually classed as second grade manganese ores and third grade ferruginous manganese ores.

## FERRO-MANGANESE

In 1909, Sir Lewis Fermor, after analysing the costs of ferro-manganese manufacture, wrote as follows: 'There seems to be room for a handsome profit in manufacturing ferro-manganese in India, and it certainly looks as if it should be worth someone's while to go seriously into the question.' Yet it was not until October, 1915, and on account

of the increase of price caused by the war, that its manufacture was commenced by the Tata Iron & Steel Co., and in November of the same year by the Bengal Iron Co. The production of the alloy in India since that time is summarized in the table below.

*TABLE XV*  
**PRODUCTION OF FERRO-MANGANESE IN INDIA**

PERIOD	TOTAL TONNAGE
1915-18	20,347 <sup>1</sup>
1919-23	16,956
1924-28	42,338
1929-33	30,633 <sup>2</sup>

To be acceptable to the market in normal times, the phosphorus content of ferro-manganese should not exceed 0.1 per cent, although much of the material sold contains 0.2 or 0.3 per cent. The phosphorus content of the alloy produced in India is believed to exceed this upper limit owing to the high percentage of phosphorus in most Indian cokes, and this is perhaps the reason why Indian ferro-manganese does not find a market abroad. By careful selection of the manganese ore employed and the use of coke from the Giridih coal-field which has a low phosphatic percentage (0.022 per cent P), ferro-manganese could doubtless be produced with phosphorus contents within the accepted limits. Dr Fermor has pointed out however, that the amount of Giridih coal is limited and that the percentage of phosphorus in the high grade ores of the Central Provinces is slowly increasing with depth from the surface, and has concluded that India can never be a large producer of low-phosphorus ferro-manganese by blast furnace methods. The possibilities of its manufacture in the electric furnace therefore deserve investigation.

In addition to the quantities used in the production of ferro-manganese, manganese ores are also added to the blast furnace charge in the manufacture of pig iron and to the open-hearth steel furnaces in India. The total quantity consumed by the companies concerned for all these purposes up to the end of 1931 was 536,025 tons.

<sup>1</sup> After satisfying the requirements of the Indian steel industry, the balance of 7,555 tons was exported to France, the United States of America, Italy and Natal.

<sup>2</sup> Production of the Tata Iron & Steel Co. Ltd. only.



## NICKEL

Nickel is found in small quantities in the lead-zinc-silver ores of Bawdwin in the Federated Shan States, and is collected in the form of a speiss in the course of smelting operations in the Burma Corporation's plant at Nam Tu. The metal may occur in the ores in the form of nickeliferous pyrrhotite, the magnetic sulphide of iron which contains varying amounts of nickel and is usually an associate of chalcopyrite. The pyrrhotite is believed to owe its nickel content to minute, disseminated inclusions of pentlandite, a sulphide of iron and nickel,  $[(Fe,Ni)S]$ . A more recent investigation of the Bawdwin ore by Dr J. A. Dunn (1935) has revealed the presence of small quantities of gersdorffite, a sulpharsenide of nickel ( $NiAsS$ ), in which part of the nickel is replaced by cobalt; and of another undetermined mineral containing both nickel and cobalt. With them occur the silver-bearing minerals pyrargyrite and freieslebenite, in addition to galena, zinc blende, and iron and copper pyrites. Regular returns of speiss production commenced in 1927, and from that time until the end of 1932, 16,671 tons had been made containing an estimated total of 4,496 tons of nickel, together with large quantities of copper and silver. The speiss, which also contains from 3 to 4 per cent of cobalt, is shipped from Burma to Germany for further treatment.

TABLE XVI

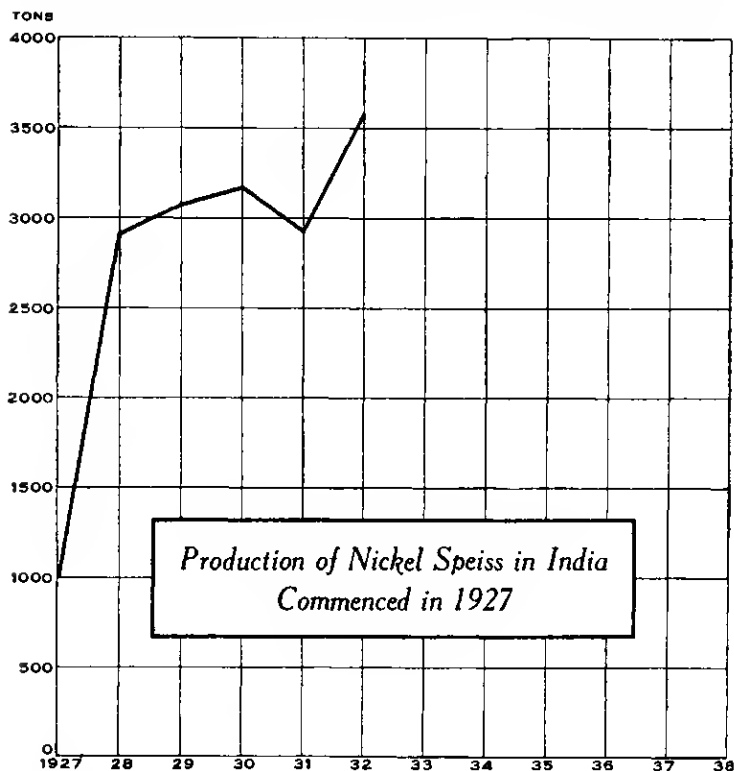
## PRODUCTION OF NICKEL SPEISS AT NAM TU

YEAR	TONS	VALUE	COMPOSITION		
			Nickel	Copper	Silver
		£	%	%	oz. per ton
1927 ...	1,032	13,176	24.64	15.92	33.58
1928 ...	2,933	39,922	24.80	15.20	32.20
1929 ...	3,065	47,670	27.08	13.16	30.03
1930 ...	3,150	53,790	30.19	10.43	28.38
1931 ...	2,911	49,924	27.63	10.75	32.32
1932 ...	3,580	77,269	25.98	12.87	32.99
TOTAL ...	16,671	£281,751			

It has been recently reported that on No. 9 level of the Bawdwin mine, the Meingtha orebody has changed almost entirely from lead to copper minerals carrying unusually high percentages of nickel and

cobalt. When these deeper portions of the orebody come to be exploited therefore, a rise in the nickel production may be anticipated.

Canada produces over 80 per cent of the world's supply of nickel; practically all of it from the mixed sulphides of iron, copper



Graph 12

and nickel associated with basic igneous rocks of the norite type in the Sudbury district of Ontario. In an official publication which appeared in 1934, A. H. A. Robinson of the Canadian Department of Mines has summarized the uses of the metal as follows: 'Though nickel does not yet rank in industrial importance with such metals as iron or copper it occupies a very important place in the arts and industries, especially in the form of alloys, to which it imparts its

highly useful properties of great strength and resistance to corrosion. Its most extensive use is in nickel steels and nickel cast irons and in Monel metal, an alloy of nickel and copper.

'Nickel steels containing from one-half to 7 per cent nickel are much used in automobile, aircraft and locomotive construction and for a great variety of machinery parts, on account of their dependability, high strength and toughness; corrosion-resisting steels, carrying 7 to 35 per cent nickel, are used for buildings, cooking utensils, turbine blades, marine fittings, chemical apparatus, etc.; and heat-resisting steels, containing 7 to 35 per cent nickel, in the construction of oil-refining, ceramic and glass-making plants, in furnace and mill parts in metal-working industries, in equipment for high-temperature chemical processes, etc.

'Chilled cast irons containing 4 to 5 per cent nickel combine toughness with great hardness and are used for crusher jaws, rolls, etc., and corrosion-resisting cast irons carrying 12 to 20 per cent nickel, for oil refinery equipment, automobile and Diesel engine parts, mine equipment, etc.

'Monel metal, a so-called "natural alloy" containing about 68 per cent nickel, 30 per cent copper and about 1.5 per cent iron, is made direct from Sudbury ore without preliminary separation of the nickel and copper. It resembles silver in appearance, is superior to bronze in durability, equals steel in strength, is amenable to both hot and cold working and finds a multitude of uses in a great variety of industries. In aircraft construction it is used for such vital parts as tanks, propeller sheathing, pontoons and landing gear; in building construction for roofs, shop fronts, ventilators and for ornamental interior work, where an untarnishing, silver white metal is desired; in the chemical industry in many types of apparatus, from evaporators to thermometer bulbs, in which easy cleansing and durability are requisites; in the food industry for sanitary packing and canning equipment. In the manufacture of equipment for household, hotel, hospital, restaurant and dining-car service, etc., it is used for kitchen table tops, laundry apparatus, cooking utensils, operating-room accessories, service counters and trucks, sinks and soda fountains; in the textile industry for dyeing and finishing equipment; in the pulp and paper industry for a variety of machine parts to protect the paper from metallic contamination.

'Other important nickel alloys are nickel-silver (10 to 30 per

cent nickel); nickel bronzes ( $\frac{1}{2}$  to 50 per cent nickel); aluminium and zinc base die castings ( $\frac{1}{2}$  to 5 per cent nickel); aluminium alloys (2 per cent nickel); nickel-molybdenum-iron alloys (60 per cent nickel); and nickel-cobalt-titanium alloy (78 per cent nickel).

'Pure metallic nickel is used for coinage in 23 countries; as an element in certain storage batteries; as a catalyser for the production of edible oils and of soaps; and for a great variety of apparatus used in the aircraft, chemical, dairy, food, petroleum, pulp, paper and electrical industries.

'Nickel anodes and nickel salts are used for electro-plating, and nickel oxide and nickel salts in the chemical industry and in under-coatings on enamelled ware.'

Even this long list does not exhaust the uses of this important metal. Some of the nickel alloys have high electrical resistances, and the wire coils of electrical heating apparatus are often made of an alloy of nickel and chromium. Steel containing 36 per cent of nickel is said not to contract or expand with normal changes of temperature, and is used for measuring tapes and other purposes where this unusual property is advantageous. Wires made from a nickel-iron alloy containing 38 per cent of nickel and plated with copper are fused into electric light bulbs to carry the current to the internal filament. The magnetic permeability of an alloy with 78 per cent of nickel is exceedingly high, and this discovery is stated to have revolutionized the manufacture of submarine cables. The alloy used by the Government of India for coinage purposes contains 25 per cent nickel and 75 per cent copper. The nickel-copper-zinc alloys, also known as German silver, contain about 50 to 65 per cent of copper, 5 to 30 per cent of nickel and 18 to 30 per cent of zinc. The average annual imports of articles made of this material into India for the five years ending 1932-33 weighed over 906 tons and were valued at Rs. 14,36,362. In 1913 the price of nickel in the United Kingdom varied between £165 and £170 per ton. At the present time (June, 1935) it costs from £200 to £205 per ton.

According to Sir Edwin Pascoe, nickel is a constituent of some importance in the copper ores of Singhbhum, Bihar and Orissa, which is at present lost in the ore dressing and smelting processes followed at Maubhandar. 'The introduction of an electrolytic plant would probably render the separation of the metal an economic proposition.' J. A. Dunn (1934) has shown that the element occurs associated with

the copper ores in the form of pentlandite, a sulphide of iron and nickel  $[(Fe,Ni)S]$ ; millerite, the sulphide of nickel  $(NiS)$ ; and violarite, another sulphide containing both iron and nickel. The presence of nickel and cobalt in the pyrrhotite of the Khetri deposit of Jaipur, Rajputana, was proved by F. R. Mallet. Nickel also occurs in the sulphide ores of the Tovala taluk in Travancore, which are mixtures of pyrrhotite, pyrite, chalcopyrite and other minerals. In April, 1934, it was announced that large deposits of garnierite had been discovered in Singhbhum, but no account of the alleged occurrence has yet been published. Garnierite is a hydrated silicate of magnesium and nickel: a soft, amorphous, green or white mineral of very variable composition. It occurs in New Caledonia in association with chromite and steatite and has been extensively mined there.

### COBALT

A complex ore of cobalt known as *sehta*, which contains the minerals cobaltite, the sulpharsenide of cobalt  $(CoAsS)$ , and danaite, a cobalt-bearing variety of mispickel, the sulpharsenide of iron  $(FeAsS)$ , occurs with copper and iron pyrites sparsely scattered in irregular strings, layers and lenticles through black slates, without any resemblance to a true lode, in the Babai copper mines of the Khetri State, Jaipur, Rajputana. The country rock is mostly black slate, siliceous and splintery, with indefinite bands of quartzite of the Ajabgarh series, in the Delhi system, and is intruded by amphibolites. The mines have been closed as far as copper is concerned for many years, and the extraction of *sehta* ceased about 1908. It used to be recovered by crushing the slate and panning the powder, the heavy concentrate so produced being sold to the Jaipur jewellers for the production of the beautiful blue glazes of their enamel work. Its place is now taken by a more expensive, but better quality, imported product containing cobalt.

Small quantities of cobalt have been detected in certain Indian manganese ores and in the sulphide ores of the Tovala taluk, Travancore; while linnæite, a sulphide of the metal  $(Co_3S_4)$ , has been recognized amongst specimens of copper ores from Sikkim.

An earthy incrustation of pink erythrite, or cobalt bloom, the hydrous cobalt arsenate  $(Co_3As_2O_8, 8H_2O)$ , is sometimes noticed on heaps of the Bawdwin lead and zinc sulphide ores after continued exposure to the weather. The metal finds its way into the nickel

speiss which is accumulated during smelting operations at Nam Tu. The speiss contains some 3 to 4 per cent of cobalt and is exported to Germany for treatment. From 1927, when shipments commenced, to the end of 1931, it is calculated that they have contained between 400 and 500 tons of metallic cobalt. It is a comparatively rare and expensive metal which in August, 1935, was quoted at 5s. 3d. per pound.

It is used in the manufacture of certain steel alloys, particularly for varieties in which high magnetic permeability, suitable for the formation of electro-magnets, is required. It is also added to some high speed steels, and alloyed with chromium and tungsten it forms 'stellite' for cutting-tools, hard surfacing work and acid-resisting receptacles. The cobalt-tungsten carbides such as 'carboly' are even harder than 'stellite'. Cobalt has also been employed for electro-plating and for thermocouples.

The ceramic industry absorbs most of the cobalt oxide which is made, and this compound has largely replaced the blue glass known as smalt. Many of the permanent blue pigments of the glass, porcelain, earthenware and enamelling industries owe their colour to various compounds of this metal.

Finally, certain other salts and particularly the resinate and oleate of cobalt, are active 'driers' for oils, superior in this respect to compounds of iron and manganese, and for this reason they find their way into the oil and paint trades.

## CHAPTER V

### CHROMIUM, MOLYBDENUM, TUNGSTEN AND URANIUM

#### CHROMITE

THE mining of chromite, an ore containing the oxides of chromium and iron ( $\text{FeCr}_2\text{O}_4$ ), began in Baluchistan in 1903, in Mysore in 1907 and in the Singhbhum district of Bihar and Orissa in the same year. The Baluchistan deposits, discovered by E. Vredenburg in 1901, consist of veins and segregated masses of the mineral distributed in ultra-basic rocks of Upper Cretaceous age, along the hills bordering the Zhob valley and the upper part of that of the Pishin river. The orebodies are of very variable shape and size and are often enclosed within a shell of serpentine; near Khanozai a mass of almost pure ore was found, about 400 feet in length by 5 feet in breadth, and containing over 54 per cent  $\text{Cr}_2\text{O}_3$ . The chief mines are near Hindubagh in the Zhob valley.

The discovery of the mineral in Mysore is due to H. K. Slater in 1905 and it has since been found, again in ultra-basic rocks, at many places in the Shimoga, Hassan and Mysore districts, notably in the Nuggihali schist belt, running south-east from Arsikere to Hulikere, a distance of nearly 20 miles. Further south, in the Mysore district between Mysore and Nanjangud, a number of patches of ultra-basic rocks have been located which carry veins, lenses and segregated patches of chromite. The most important of these is a narrow strip of brownish serpentine, running north and south for two miles, near Shinduvalli, the serpentine being enclosed in gneiss. For a distance of a mile or so near the middle of this strip, a number of small, nearly vertical, veins of solid chromite occur, varying in thickness from an inch to a foot or more and widening into lenses of bigger dimensions in depth. The ore is massive, of good quality, and broken by veins of magnesite which also traverse the country rock.

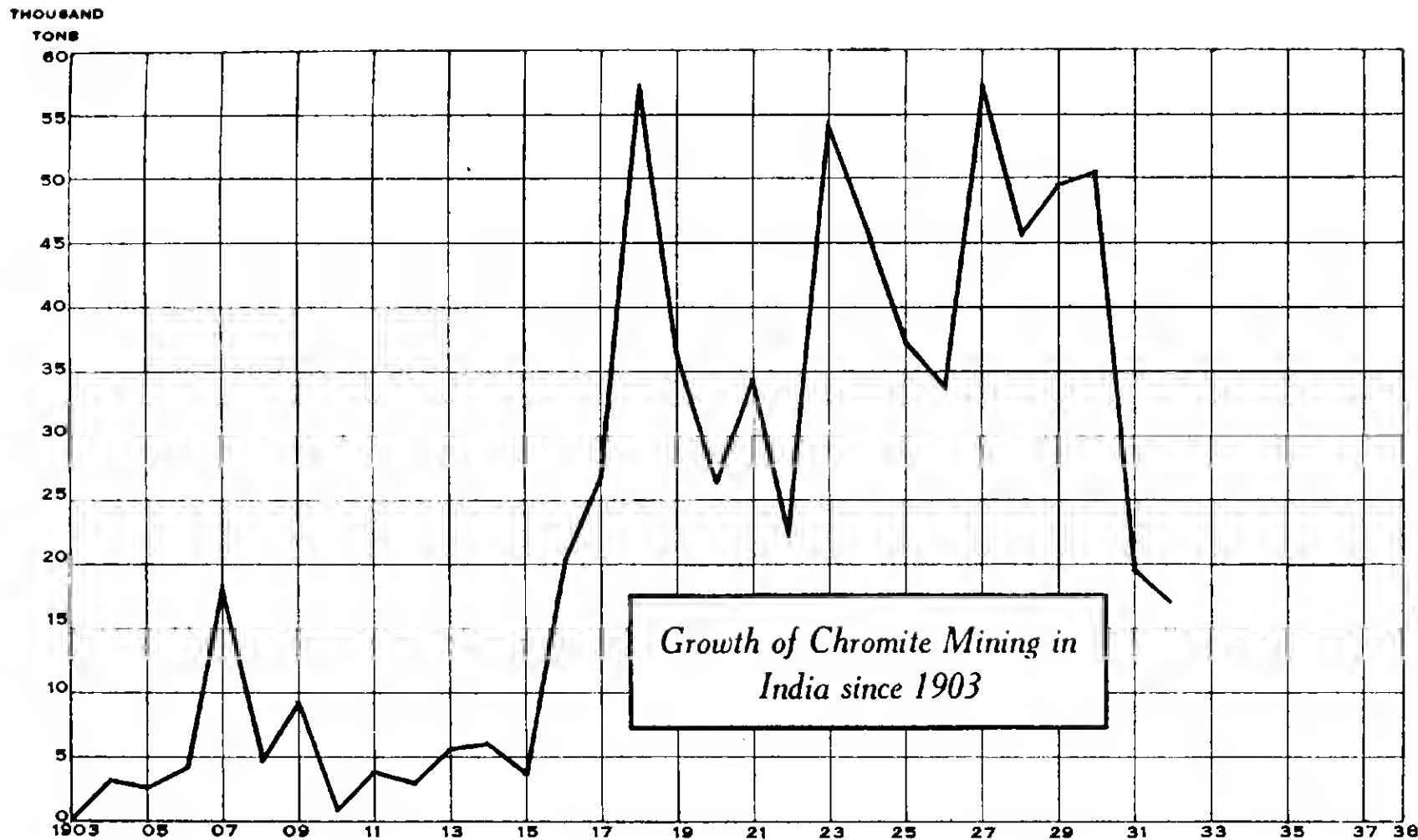
The chromite deposits of Singhbhum, found by R. Saubolle in 1907, lie in the Jojohatu area, west of Chaibasa, as segregations and

bands in partially serpentinized, ultra-basic rocks, such as saxonite, pyroxenite, lherzolite and dunite. The veins are up to 3 feet thick, but J. A. Dunn states that they are lenticular and may extend sometimes 100 feet along the strike or down the dip. They are regarded as primary segregations from the ultra-basic magma, which owe their drawn out and banded characters to earth movements.

Chromite has been found in many parts of the Indian Empire, but the only deposits of commercial importance known are those already described. The mineral is associated with the serpentines and peridotites of the Arakan Yoma; of the Myitkyina district, Burma; and of the Manipur State. It has been found near Port Blair in the Andaman Islands. Thin veinlets ramify through parts of the magnesite deposits of the Chalk hills, Salem district, Madras, whence about 100 tons are believed to have been exported to the United Kingdom in the forties of the last century. New chromite localities were noted in 1928, from Hotag, Ranchi district and Baida Chauk, Bhagalpur district, Bihar.

The chief uses of chromite are as a source of ferrochrome, metallic chromium (with its increasing uses in plating), and the chrome steels; as a refractory material which furnishes a neutral lining for steel, lead and copper furnaces; and finally, as a source of chromium salts. Ferrochrome is an alloy of chromium and iron, containing from 60 to 70 per cent of chromium, which is used in the manufacture of chrome steels. The latter may be broadly divided into groups which contain iron, carbon and chromium, and others which contain these elements and some other metal, such as nickel, manganese, tungsten or molybdenum. These steels are used for the wheel-tyres and springs of railway rolling stock, armour plate and armour-piercing shells, and for machinery parts subjected to excessive wear. Amongst the second group are the stainless and rustless steels and various other alloys which are made into cutting tools. The steel of which stainless knives are made contains about 13 per cent of chromium. The strong and tough, yet ductile and malleable, stainless steels now so widely used for domestic purposes, contain about 18 per cent of chromium and 8 per cent of nickel. The chromates and bichromates are of great importance in the arts, the latter being employed in the manufacture of dyes and of chrome alum. They also find outlets in tanning, paint making, calico printing, photography and in many other trades. Lead chromate is an essential constituent of many yellow, blue, green and red pigments.





Graph 13

From the commencement of mining operations in India up to the end of 1932, a grand total of 824,141 tons of chromite of a reported value of Rs. 1,33,84,416 had been produced. Of this figure 392,187 tons were from Baluchistan, 374,690 from Mysore and the remainder from the Singhbhum district of Bihar and Orissa. For the four years ending 1932, the average annual tonnages were 13,927 (valued at Rs. 2,07,363; 15,920 (Rs. 2,89,143) and 4,659 (Rs. 78,476) from the three regions in the order named, respectively.

With the exception of small quantities retained in India for the manufacture of chromite refractories, the whole of the production is exported, mainly to the United States, Germany and the United Kingdom. The chief producing countries are Southern Rhodesia and New Caledonia, with smaller but important amounts from the Union of South Africa, Greece, Jugo-Slavia, Russia, Cuba and Asiatic Turkey.

Chromite bricks are made in India by the Tata Iron & Steel Co. Ltd. and by Messrs. Burn & Co. Ltd. at their Raniganj works. The internal demand, limited as it is at present to the steel works, is but a small one.

Experiments in the smelting of chromite and in the decarburization of high carbon ferrochrome in the electric arc furnace were made at the Central College, Bangalore, and at Bhadravati, using a half ton Héroult furnace, in 1931-32, but were abandoned. It has been officially stated that until the depression stopped operations, the departmental mining of chromite in Mysore resulted in large profits to the State.

### MOLYBDENITE

Molybdenite, the disulphide of molybdenum, which greatly resembles some forms of graphite in its natural state, is a lustrous, lead-grey, metallic-looking mineral which can be split into thin leaves by the finger nail. Sometimes large pieces occur in short hexagonal prisms. It has been found in small quantities at many places in India including various parts of Chhota Nagpur, chiefly in the Hazaribagh district, as, for example, with lead, zinc and copper sulphides, near Mahabagh; at Baragunda and elsewhere. It is known to occur in a pegmatite vein at Kunnavaram, Godavari district, Madras, and under similar conditions associated with pyrrhotite at Mangamalai, Travancore, while the elæolite syenites of Kishengarh in Rajputana also contain small amounts. The most important occurrences are in

Burma, in association with the wolfram- and cassiterite-bearing veins of that province. It has been found at Byingyi in the Yamethin district and at many localities in Tavoy and Mergui. Mines where it is more abundant than elsewhere include Sonsinpaya, Wagon North, Kadantaung, Thingandon and Widnes, all in the Tavoy district. Sometimes it occurs in the granites which have undergone alteration in the vicinity of the veins, more usually in pegmatites, in greisens, in veins with wolfram or cassiterite, or with both these minerals, or, more rarely still, in veins in which it occurs alone or with a little pyrite. In the mixed veins it usually lies close to the walls and is often intergrown with the mica which nearly always occupies such positions, and it is commoner in veins traversing granite than in those which pierce sedimentary rocks. Small parcels of the ore have been shipped from Burma from time to time, the largest being one of 27 cwt., valued at £626 in 1917, and the total only amounting to 46½ cwt., valued at £1,022, the last shipment being made in 1921. Owing to primitive mining methods and the absence of proper concentrating machinery, the deposits have never received the attention which they deserve, and the mineral may some day prove a valuable by-product of tin and wolfram mining.

The metal and its alloy, ferro-molybdenum, are used in conjunction with other metals, such as chromium, nickel, tungsten and vanadium, to impart desirable properties to special steels; thus they may be used to increase the tensile strength, elasticity, toughness, hardness and resistance to shock, fatigue and exposure. Such steels are used for big guns, rifle barrels, propeller and crank shafts, armour-piercing shells, light armour plate, high speed machine tools and in general automobile engineering. The price of molybdenite was £1-14-6 per unit c.i.f. for 80 per cent concentrates in September, 1935.

## TUNGSTEN

Wolfram, a tungstate of iron and manganese, is the chief ore of tungsten and this metal is an essential ingredient of the high-speed cutting steels so much used in modern machine shop practice. Under favourable conditions, one man with one lathe can do as much work with high-speed steel as five men and five lathes could perform formerly with simple carbon steel tools. It has been quite correctly stated that to deprive a nation of tungsten is to cripple its military power and to ruin its industrial life in times of peace. Tungsten

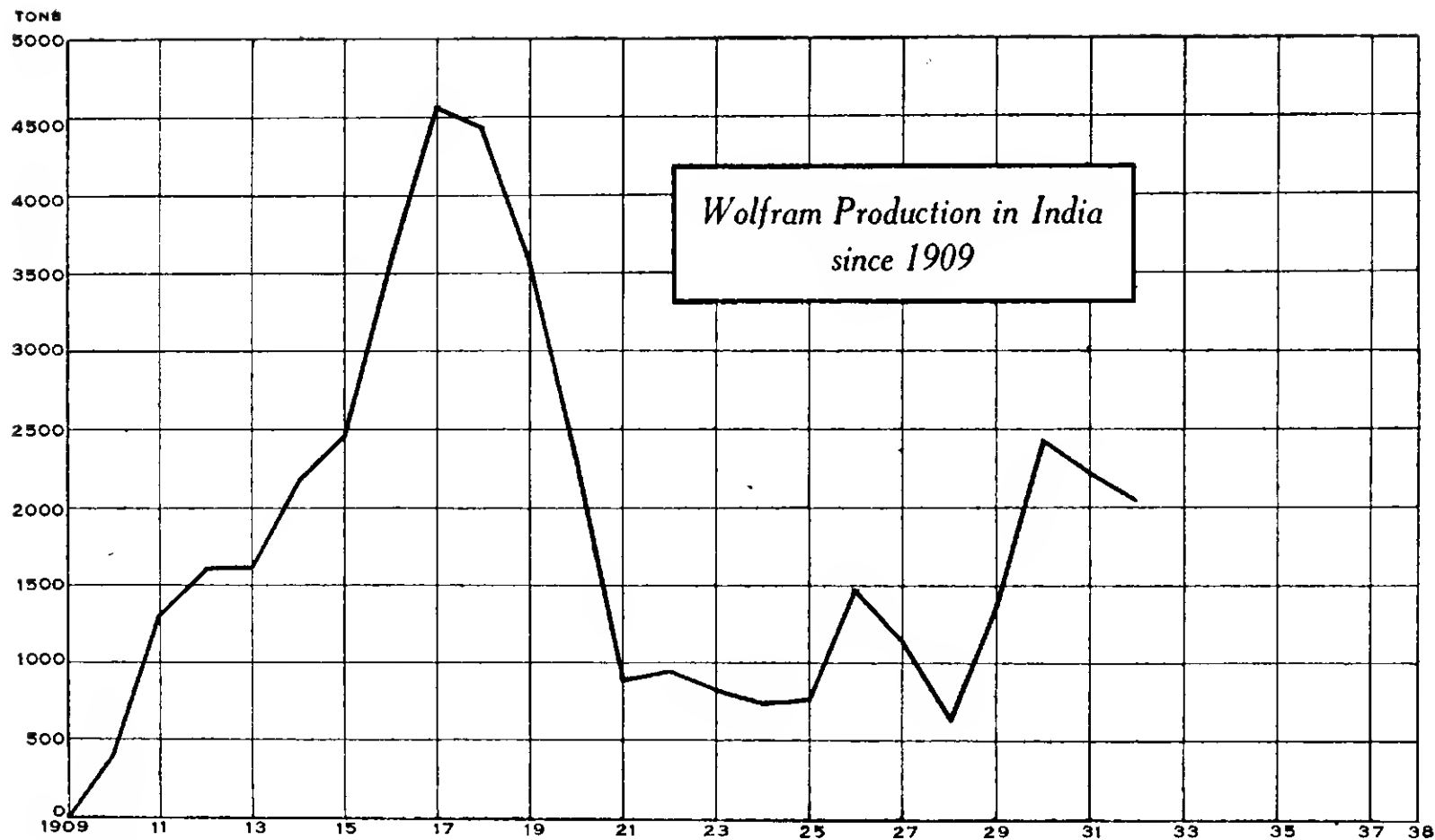
has numerous other uses, especially for the preparation of the metallic filaments of incandescent electric lamps, millions of which are now made annually.

The mineral occurs in quartz at its junction with mica schists of Dharwarian age near Kalimati, Singhbhum district, Bihar and Orissa; at Agargaon, Nagpur district, Central Provinces, sparsely scattered in veins and stringers of quartz interbedded with mica schists and tourmaline schists of Dharwar age; and near Degana, Marwar, Rajputana, in veins of quartz and biotite mica, with fluorite and small quantities of the phosphates, triplite and libethenite, penetrating granite perhaps of Siwana age, intruded into Aravalli phyllites. These deposits however, are quite insignificant when compared with those of Burma, where quartz veins containing wolfram have been found at intervals over a distance of 750 miles, from the Yengan and Mawnang States of the Federated Shan States in the north, through the districts of Yamethin, the Bawlake State of Karenni, to the Thaton, Amherst, Tavoy and Mergui districts in the far south. In all these localities the wolfram and cassiterite-bearing veins are most intimately associated with the intrusive biotite-granite which forms the cores of the mountain ranges of the Indo-Malayan system, stretching further south still through western Siam to the Malay Peninsula. In Lower Burma the granite is intruded into a series of shales, slates, argillites and agglomerates with subordinate quartzites, limestones and conglomerates, of unknown age, known as the Mergui series. Both wolfram and cassiterite occur very sparingly as accessory minerals in the granite. They are also found in pegmatite and aplite veins and in greisen bands which traverse it. The mineral-bearing quartz veins however, are of greater importance, and they occur either in the granite, penetrating its contact with the sedimentary rocks, or enclosed within the latter themselves at no great distance from the granite. Under the influence of denudation the veins shed their metallic contents into the eluvial deposits of the hillsides, from which a great deal of wolfram and tin stone have been won. The latter mineral also finds its way into the true alluvial deposits of the river valleys. The deposits were formed partially under conditions closely allied to strictly magmatic ones, and were also produced by processes in which gaseous agencies, including compounds of fluorine and sulphur, to some extent played a part, and in rare cases by hydrothermal reactions which followed as a consequence of the former ones.

The wolfram-bearing area of the Yamethin district lies in the extreme east, close to the summit of Byingyi (6,254 feet), where the veins are in granite and carry molybdenite with copper and iron minerals, as well as wolfram. The Mawchi mine in Bawlake State, Karenni, possesses at least ten important veins, varying from 2½ to 5 feet in thickness, which are all in granite. In the Thaton district, four parallel veins only a few inches thick have been traced for 2½ miles. They carry tourmaline which is an unusual associate. The deposits of the Mergui district lie near Palauk where the veins occur in both granite and sedimentary rocks, at Tagu in the valley of the Great Tenasserim and elsewhere. The Tagu veins are remarkable for their large size, varying from 3 to 15 feet in thickness; they are all in granite and carry arsenopyrite and chalcopyrite.

The Tavoy district is by far the most important, and in 1918 there were over 100 producing concessions, which ranged from shallow workings operated by primitive eastern methods to deep mines fully equipped with efficient concentrating plants. The largest mines are at Hermyingyi, Widnes, Kanbauk, Taungpila and Kalonta. In addition to wolfram and cassiterite, the Tavoy veins carry mica (practically always), fluorite (often), molybdenite (sometimes), pyrrhotite (in some cases), galena (rarely), zinc blende (rarely), arsenopyrite (rarely), native bismuth (rarely), bismuthinite (rarely) and topaz (in a single case only).

'The tungstate of iron, or wolfram sand,' wrote Dr Mason in his classical account of Tenasserim, published in 1849, 'much resembles tin, and it is found in most neighbourhoods where that ore is obtained, and for which it is often mistaken.' The mineral, however, was completely overlooked until 1908 when it was rediscovered *in situ* by J. J. A. Page. Mining commenced in 1910, and in 1911 an output of 1,300 tons made Burma the chief wolfram-producing country in the world, a position she occupied in 1914 when the World War found the British Empire dependent on Germany for its supplies of tungsten. The situation was successfully dealt with, and between 1914 and the Armistice no less than 17,642 tons, of a total value of £2,323,000, were exported, and of this quantity 14,000 tons came from the Tavoy field alone. The boom created by the war stimulated wolfram production in other countries too, and in 1916 both the United States of America and Bolivia outstripped Burma. By 1917 large quantities were also exported from China, which rapidly became the largest



Graph 14

producer in the world. Stagnation followed the boom, and in the succeeding quinquennium the Indian output dropped to an annual average of 1,726 tons, while the years 1924-28 witnessed a further decline to 955 tons as an annual average, most of which was probably obtained as a by-product in mining operations primarily conducted for the recovery of tin ore. In more recent years still, better prices have led to an improvement, and the average annual figures for the four years ending 1932 were 2,018 tons, valued at £91,372. Of this amount, 50.3 per cent came from the Tavoy district and 45.5 per cent from the Mawchi mine in Karenni.

## URANIUM

The earliest reference to a uranium mineral in India appears in a German periodical published in 1860 in which Emil Stoechr records the occurrence of copper uranite, an old name for torbernite, the hydrated phosphate of uranium and copper  $[\text{Cu} (\text{UO}_2)_2 \text{P}_2\text{O}_8 \cdot 8\text{H}_2\text{O}]$ , on Lopso hill, Singhbhum, and it is interesting to note that another occurrence of torbernite with uranium ochre, as an incrustation on the magnetite-apatite rocks of Sungri in Dhalbhum, has been listed by Sir Lewis Fermor. To Sir Thomas Holland is due the first recognition of pitchblende in India. Discussing in 1901 an occurrence of triplite, a phosphate and fluoride of iron and manganese, at a mica mine two miles south-east of Singar in the Gaya district, Bihar and Orissa, he added, 'the locality also yielded small specimens of the more valuable mineral uraninite (pitchblende), associated with uranium ochre and the beautiful torbernite, a phosphate of uranium and copper'. R. C. Burton examined the locality in 1912 and found the pitchblende in a wide pegmatite which had been mined for many years for mica, intrusive in muscovite schists, at Abraki Pahar, due east of Bhanenkap. The mineral occurs as rounded nodules in all sizes up to a maximum of 36 lb. in weight, distributed in basic segregations of the pegmatite. Triplite, generally associated with large masses of ilmenite, usually forms the outer ring of these basic patches, though occasionally the pitchblende lies in the centre of felspathic nodules. White and yellow micas, tourmaline, zircon and torbernite also occur. The pitchblende is normally surrounded by a rim of uranium ochre. About 6 cwt. of the mineral was recovered from this locality during prospecting operations in 1913-15.

Another locality lies five miles to the north-north-west near

Pichhli, in the same district, and will be mentioned under COLUMBITE. Here, according to G. H. Tipper, the mode of the occurrence of the pitchblende in the pegmatite is much the same, and small nodules of the mineral, up to two inches or more in diameter, deeply altered into uranium ochre, are found. Torbernite, of a bright green colour, and lemon yellow incrustations of autunite also occur. The latter has a similar chemical constitution to torbernite, with its copper replaced by calcium. Other accessory minerals include columbite, monazite, black tourmaline and pink garnet.

The uranium ores are the source of radium, which occurs in all of them in exceedingly small quantities; but this element is valuable enough to make their extraction profitable even when only one part of radium occurs in many million parts of the mineral. It is said that the world's total existing supply of radium is less than 600 grammes, or a little over a pound, and that this is being added to at the rate of not more than 60 grammes a year. Besides the revolution which it has caused in the physical, chemical and electrical sciences and the alterations it has brought about in earlier fundamental conceptions of matter, radium has applications in many branches of experimental work, and the use of its salts in the treatment of malignant disease is widespread. The chief sources of pitchblende until comparatively recent times were the cobalt-silver veins of the Erzgebirge on the borders of Bohemia and Saxony, but supplies now come from the Belgian Congo and Czecho-Slovakia, and more recently still new reserves have been discovered in northern Canada.

Uranium salts impart a beautiful greenish-yellow fluorescence to glass and are also used to a small extent in the ceramic industry for the decoration of pottery and tiles.



## CHAPTER VI

### ANTIMONY, ARSENIC, BISMUTH, TANTALUM AND NIOBIUM

#### ANTIMONY

THE existence of antimony ores near the Shigri glacier in Lahaul, Punjab, has been known for 80 years, and a consignment of 15 tons of stibnite (antimony trisulphide) from this locality reached England in 1905. The lodes are thick, contain stibnite with its decomposition products, cervantite and kermesite, occur in gneissose granite and are associated with argentiferous galena, zinc blende, pyrite and manganese siderite. It is reported that some of the stibnite contains small amounts of gold. The inaccessibility of the neighbourhood, its elevation of 13,500 feet beyond the Hamta pass (14,500 feet), and its climate, which is rigorous enough to limit work to two or three months in the year, have hindered any active exploitation up to the present time.

The antimonite deposits of Thabyu, in the extreme south-east of the Amherst district, are close to the Siamese frontier. A. M. Heron states that the veins are very large, the biggest measured being at least 20 feet thick and traceable for 600 feet. The ore consists of radiating or parallel crystals, or massive aggregates of stibnite, superficially oxidized to cervantite and stibiconite. The vein stuff is a calcareous chert showing distinct brecciation and often a cellular structure. The country rocks are black fissile slates of unknown age. Small angular fragments of slate occur in the veins, which are believed to fill tension cracks, and to have been deposited during periods of upheaval, at moderate depths, from solutions at comparatively low temperatures. During times when high prices have ruled in the markets for metallic antimony, large quantities of ore have been obtained from Thabyu and other localities in the Amherst district. Thus in 1916, they supplied upwards of 1,000 tons, but in more normal years, the distance of the deposits from any modern ways of transportation renders their working unprofitable.

A narrow quartz vein containing stibnite has been traced for 600 or 700 feet in slates which form the crest of a low ridge on the western slopes of the eastern of the two parallel ranges of the Thaton-Martaban hills, seven miles to the east of Katun railway station, in the Thaton district, Burma. Thaton district is adjacent to Amherst on the north.

The stibnite deposits of the Southern Shan States were examined by H. C. Jones, who concluded that none of them appear to be large or of much economic importance. They occur at the following localities: Naking and Loi Hke in Mong Hsu, Mong Ing in Kengtung, Hkomhpok and Loi Hsang in Mong-Kung. The stibnite usually exists in a bladed, striated variety and more rarely in drusy and massive forms. The oxidized ores valentinite and cervantite are common. The Naking deposit, which in 1908 yielded about 1,000 tons of ore, consists of stibnite irregularly deposited through a vein in sandstone, perhaps of Jurassic age. Some of the others appear to be quartz-stibnite veins in Plateau limestone.

Small quantities of stibnite and antimony ochre have been won from veins and patches in a quartzose rock in the schists at Chikkannanahalli, in the Chitaldroog district of Mysore. The veins are about two inches in thickness, swelling in places to wider lenses up to a foot or so in width. Prospecting operations have shown that the grade of the orebody would have to improve considerably before work under normal conditions could be entertained. (Smeeth and Iyengar.)

Antimonial lead, containing approximately 77 per cent of lead, 21 per cent of antimony and from 6 to 8 oz. of silver to the ton, is produced as a by-product at the Nam Tu smelters of the Burma Corporation Ltd. During the Great War the requirements of the Indian Ordnance Department were met from this source, and large quantities have been exported to the United States of America since then. Official statistics only commenced in 1924, and from that year until 1931, a total of 9,500 tons of antimonial lead, valued at £167,114, has been made. This is estimated to have contained approximately 1,900 tons of metallic antimony. The annual production of antimonial lead now varies between 1,500 and 1,700 tons per annum.

Metallic antimony is an essential component of most of the 'anti-friction', 'white' or 'bearing-metals', which also contain lead and tin, and of which the average annual imports for the five years ending 1932-33 were 248 tons, worth Rs. 2,98,610. Alloyed

with tin and small quantities of copper and zinc it forms the 'Britannia metals' employed in the manufacture of cheap table ware. The 'type-metals' used in printing are alloys of antimony, lead and tin, characterized by their fusibility and power of expansion on solidification. Antimony also forms part of the alloys known as pewter, solder, white bell metal and hard lead. Indian imports of solder for the five years ending 1932-33 averaged 312 tons, valued at Rs. 4,13,170. Antimonial lead is cast into battery plates, shrapnel and other bullets.

Antimony trioxide, or 'antimony white', is employed as a white pigment. The tetroxide forms an opaque white glaze for enamelling ironware. The red trisulphide is used as a pigment, in the vulcanizing of rubber and in the manufacture of safety matches. 'Antimony yellow' is obtained by oxidizing the sulphide, and mixed with red lead and zinc white it forms a number of yellow pigments known as the 'Naples yellows'. These are used in oil painting and in the glass and ceramic industries. Other antimony compounds are used as mordants in dyeing, while certain of its salts find extensive applications in medicine.

## ARSENIC

The orpiment mines of Chitral are of great age, and small quantities of the mineral are still won from them, though no returns of production have been available for over 25 years. According to G. H. Tipper, there are six principal areas in which the mines are situated, lying between 11,000 and 16,000 feet above sea level. The bright lemon-yellow trisulphide of arsenic, orpiment, is usually accompanied by the brilliant aurora-red monosulphide, realgar, and by fluorspar, the minerals occurring close to a band of basic rock intrusive into calcareous shales associated with marble. There are believed to be good prospects of discovering fresh deposits of the mineral in Chitral.

Orpiment and realgar occur in scattered fragments on the moraines of the Shankalpa glacier in Kumaon, where they are collected and sold locally, doubtless furnishing part of the supplies of the cities in Northern India, for the minerals can be purchased in almost any bazaar.

F. R. Mallet described a seam of arsenical pyrites about one foot thick, in quartz schist, at an elevation of 4,000 feet, on Samphar

hill, Kalimpong sub-division, Darjeeling district, Bengal. The mineral made up two-thirds of the seam and was associated with pyrite and chalcopyrite. Arsenical pyrites, which is also known as arsenopyrite and as mispickel, is a silver-white mineral which when pure contains 46 per cent of arsenic.

The occurrence of the iron arsenides, lollingite and leucopyrite, in the mica-bearing pegmatites of the Hazaribagh district, Bihar, is of no economic importance.

Orpiment has been imported into Burma from the Chinese province of Yunnan for a great many years. The writer was the first European to visit the mines, which lie at an elevation of 8,000 feet, two days' journey to the south-west of Ta-li Fu. The deposit is confined to a band of quartzite about four feet thick, of Permo-Triassic age, which has been thoroughly shattered in all directions. Orpiment and realgar have been deposited in the bedding, joint and fracture planes, and to some extent have replaced the minerals of the rock itself, forming irregular strings which swell into patches and bands of solid ore.

As its name indicates, orpiment (a corruption of the Latin 'auripigmentum' or 'golden paint') finds a direct use in the manufacture of Indian ornamental lac wares and of Burmese lacquer work. Powdered and mixed with gum it produces a so-called 'gold lacquer', while with indigo it forms green tints. In the designs of Afridi wax cloths advantage is taken of the colour of orpiment. The mineral is also widely utilized in the east as a depilatory.

The quantity of orpiment coming into Burma from Yunnan used to vary between 200 and 500 tons per annum, but the abandonment of the compilation of trans-frontier trade returns in 1924 makes it impossible to comment on the existing state of the industry.

Practically the whole of the arsenic compounds of commerce, with the exception of these coloured sulphides, are obtained as by-products in the metallurgical treatment of other ores, and there is a small but rather steady demand for them in India. Thus, during the five years 1913-14 to 1917-18, India imported approximately 100 tons of arsenic and its oxide per annum, while the average of the retained imports for the three years ending 1931-32 was 121 tons valued at Rs. 1,08,904.

Arsenious oxide or white arsenic is employed in glass-making, in the fixing of aniline colours, in the manufacture of pigments such as

'Paris green', in pyrotechny and in medicine. Large quantities of soluble arsenic compounds find an application, by reason of their poisonous properties, in the preparation of insecticides, fungicides, bactericides, sheep and cattle dips, and weed and vermin-killers. They are also used in taxidermy and tanning.

## BISMUTH

Native bismuth and its sulphide, bismuthinite, occur in small amounts in some of the wolfram and cassiterite-bearing veins of the Tenasserim division, in Lower Burma, as, for example, in those of Kanbauk, Kalonta, Zimba and Putletto in Tavoy and Palauk in Mergui. The bismuth minerals originated from the granite there, as those of tin and tungsten have also done, but they belong to a later phase of ore deposition. The veins shed their metallic contents into the surface soil and the eluvial deposits on the hillsides are often profitably treated for their wolfram and tin ore contents. The bismuth minerals are either hand-picked from the clean concentrates on the spot or recovered by chemical means from the tin ore after magnetic separation. The native bismuth is always very oxidized and its coating of bismuth ochres causes it to resemble rounded pieces of dirty, yellowish-grey stone, but on breaking these heavy pieces there is usually a bright, silvery, metallic kernel within. Small quantities are doubtless wasted because of ignorance of their properties and value, and the insignificant amounts which appear in official statistics of production only represent the hand-picked material. From 1917, the date of the first record, up to the end of 1931, 9 cwt. worth £264, has been shown in the returns. The future output thus depends entirely on their separation as by-products of the wolfram and tin-mining industries, and when every allowance is made, it must be admitted that the quantities probably obtainable from known deposits are likely to remain comparatively insignificant.

The price of metallic bismuth has fallen from 12s. 6d. in 1920 to 3s. 6d. per lb. in September 1935. It finds its main employment in the manufacture of fusible alloys which melt at comparatively low temperatures and are themselves used as fuse wires, in automatic fire sprinklers, safety plugs for boilers and heating apparatus, special solders, dental amalgams and bearing metals. Several bismuth compounds have important applications in medicine.

## COLUMBITE AND TANTALITE

Columbite and tantalite are the niobate and tantalate of iron and manganese respectively  $[\text{Fe}, \text{Mn}]$ ,  $[(\text{Nb}, \text{Ta})_2 \text{O}_6]$ , hard, black, massive or orthorhombic minerals which pass by insensible gradations from normal columbite, the nearly pure niobate at one end of the isomorphous series, to normal tantalite, the almost pure tantalate at the other. As niobium is only about half the weight of tantalum, the specific gravity of the mineral changes with its chemical composition, becoming greater as the tantalum percentage increases, and ranging from 5.3 in columbite up to nearly 8 in tantalite. This affords a rough method of determining in the field to which end of the series any particular specimen belongs. Indian examples as a rule are richer in niobium. The minerals have now been identified from about ten localities in India, from Mysore in the south to Kashmir in the north, of which only a selection can be briefly referred to here.

The earliest mention of the minerals occurs in a report of the Madras Museum for 1855, ferro-tantalite (an old name for tantalite) having been identified by E. Balfour from a specimen collected by a missionary at Palni, 69 miles north-west of Madura.

In 1894, Sir Thomas Holland found columbite in lumps, embedded in the quartz of a very coarse-grained pegmatite vein, intruded into a mica schist which is crowded with tourmaline crystals at Pananoa hill, Monghyr district, Bihar and Orissa. Tantalite occurs in the same locality. The minerals also occur in small quantities in some of the mica-bearing pegmatites of the same province.

About 1900, B. Jayaram discovered a pegmatite vein traversing a hornblende-granitoid gneiss,  $3\frac{1}{2}$  furlongs north of Masti, Bangalore district, Mysore, which he states 'is singularly rich in a dark mineral, probably columbite'. According to P. Sampat Iyengar, columbite has been noticed at Yadiyur, close to Bangalore, on the Kankanhalli road, where it is associated with beryl and samarskite in small quantities. The mineral is known to occur at other localities in Mysore and its only recorded production—up to 1931—of 112 lb. in 1913, was from this State. In 1931, 100 lb. of columbite was produced in the Monghyr district of Bihar and Orissa.

Crystals of columbite of varying sizes and up to more than six kilos in weight, arranged as fan-shaped aggregates in the felspar of a mass of pegmatite, intruded into garnetiferous mica schist, near Pichhli, Gaya district, Bihar and Orissa, were described by G. H. Tipper in

1919. The pegmatite had been prospected for mica, and the rarer accessory minerals included pitchblende and monazite. The mineral also occurs in a pitchblende-bearing pegmatite at Abraki Pahar, five miles to the east-south-east.

Mr T. Crook, Principal, Mineral Resources Department, Imperial Institute, London, has courteously supplied the following information regarding the uses of the metals. The present market requirements for tantalite are small and there is also a slight demand for ores containing a good percentage of niobium. The London price for metallic tantalum in March, 1934, was about £15 per lb. The chief uses of the metal at present are in rectifying apparatus for the conversion of alternating into direct current; in the manufacture of the spinnerets used in the production of artificial silk; in the electrodes of wireless transmission valves; in dental and surgical instruments; and as a lining to pipes to withstand the corrosion of acids, to which the metal offers extraordinary resistance. Mixed tantalum and niobium metals or certain compounds obtained from columbite, for example, the monocarbides, cemented with tungsten or molybdenum, are marketed as steel-cutting materials. Ferro-tantalum-niobium, as marketed in the United Kingdom, is stated to contain 80 per cent tantalum-niobium and to be used as an addition to high-speed steel and, with high tungsten contents, to produce an alloy for the tipping of cutting tools. Tantalum carbide is also used alone as a cutting agent and is now often mounted on shanks of pure molybdenum. Tantalum is no longer used for filaments in electric lamps.

## PART III

### OTHER USEFUL MINERALS



## CHAPTER VII

### MATERIALS USED IN BUILDING CONSTRUCTION, ETC.: BUILDING STONES, BRICK AND TILE CLAYS, CEMENT, LIMESTONE, MARBLE, SLATE AND GYPSUM

#### BUILDING STONES

THERE are no reliable statistics in existence from which the extent of the trade in building stones, and related materials such as clays, lime or road-metal may be studied, for although the output of some of the larger concerns is known accurately, the returns for the country as a whole are mere guesses. The stones used in any particular area depend almost entirely on the type of rock lying nearest to hand. In the cities of the plains, most of the buildings are usually built of locally made bricks and coated with stucco, but in many others the surrounding tracts furnish supplies of stone when these are required for more important purposes. To attempt even to summarize our knowledge of Indian building stones in a brief compass is an impossible task, and all that can be done here is to invite attention to some of the better-known examples.

There are few places in Southern India where crystalline rocks such as granites, gneisses and charnockites are not available, and they have been used from the time of the builders of the prehistoric megaliths onwards. Many of the older Dravidian temples are built of carved crystalline rocks, 'the elaborate patterns on which are as sharp as when they left the sculptor's hands'. In general, the Archæan formations wherever they occur may be relied upon to supply building and ornamental stones of great variety.

The soft Tertiary rocks of Central and Lower Burma are remarkably deficient in building products, so much so that the foundations of roads recently made through parts of the 'Dry Zone' there, have been laid on silicified fossil wood, which is abundant in the surrounding friable Irrawaddy sandstones. For the supply of stone to Rangoon and other places, large quarries were opened under

official auspices in the gneissose granite of Thaton district. A similar rock was taken in large quantities from Kalagauk island, off the Amherst coast, for the Rangoon River Training scheme.

Much of Western and Central India, Bombay, the Deccan and parts of the Central Provinces are occupied by eruptive lavas generally called the Deccan Trap, which prevail over an area of about 200,000 square miles. In many localities they furnish an excellent building stone, provided the proper varieties are chosen, while the Lameta or infra-Trappean heds of the Central Provinces yield a good ragstone which has been successfully employed in bridge building. On the other side of the peninsula, the traps of the Rajmahal hills have been quarried for centuries. They supply Calcutta with road metal and have been used in river training works on the Ganges.

Several of the Indian geological formations furnish sandstone suitable for building and engineering works generally, but amongst them pride of place must be given to the Vindhyan system, which from the time of Asoka (269-232 B.C.) onwards, has yielded incomparable materials in which the craft of the stonecutter and the skill of the architect have left enduring expression. The Kaimur sandstones of this system are quarried at Dehri-on-Son, in the Shahabad district of Bihar and Orissa. Further west, at Mirzapur, Chunar and elsewhere in the United Provinces, they have been worked for ages, and the stone is well known throughout the Lower Ganges valley as far as Calcutta for its superb qualities. It is fine-grained and compact, of reddish-yellow or greyish-white colours, and is very durable. The beds often spread for long distances without joints or fissures so that very large blocks can be obtained. From the Chunar region Asoka is believed to have obtained his pillars, great monoliths weighing up to 50 tons which, polished and inscribed, were erected at localities often hundreds of miles away. Regarding his ancient workmen Vincent Smith has written: 'The skill of the stonecutter may be said to have attained perfection. Gigantic shafts of hard sandstone, thirty or forty feet in length, were dressed and proportioned with the utmost nicety, receiving a polish which no modern mason knows how to impart to the material. Enormous surfaces of the hardest gneiss were burnished like mirrors, bricks of huge dimensions were successfully fired, and the joints of masonry were fitted with extreme accuracy.' The richly sculptured Bharhut railing, now one of the treasures of the Indian

Museum in Calcutta, and the red sandstone *stupa* at Sanchi (Bhopal), with its ornate gateways, 34 feet in height, are further noble records of this early age of Indian work in Vindhyan sandstone. In Central India the forts, temples and palaces of Gwalior are built of similar material.

The ornamental capital which surmounted the Sarnath monolith near Benares is described by Sir John Marshall as a masterpiece—the finest carving that India has produced, and unsurpassed by anything of its kind in the ancient world.

‘Perhaps the most important quarries in India,’ wrote V. Ball, ‘are those in the Upper Bhanders (the uppermost series in the Vindhyan system), to the south of Bharatpur and Rupbas, in Rajputana and Fatehpur Sikri in the Agra district of the United Provinces, which have furnished building materials since before the commencement of the Christian era to the cities of the adjoining plains. Portions of the Taj at Agra, Akbar’s palace at Fatehpur Sikri, the Jumma Masjid and, it may be added, many other magnificent mosques and tombs and generally the grandest and meanest buildings in Agra, Delhi and Muttra have drawn upon these quarries for their materials.’ The *Ain-i-Akbari*, written by Abul Fazl in 1590, refers to the ‘red stone, which is cut out of the mountains of Futtapore’ and used for building purposes, and it mentions the prices at which the Emperor Akbar permitted both rough and dressed kinds to be sold. Further west in Rajputana, the hills near Jodhpur are capped with sandstones of Upper Vindhyan age from which, according to T. D. La Touche, ‘inexhaustible supplies of the most excellent building stone may be obtained. The finer beds afford material not only for the walls of houses, but also for beams to support the ceilings, as well as flags for roofing and flooring. The stone is of a soft reddish tint, is easily worked and thoroughly durable, and is susceptible of the most delicate carving. Splendid examples of its architectural capabilities may be seen in the old palace and fort at Jodhpur’. Thus the Vindhyan system furnishes an immense tract in India, stretching from Bengal to the Punjab and Rajputana, with stone of an unsurpassed quality of which are built the finest edifices and cities of the Gangetic valley, the religious memorials of the Maurya period, the proudest monuments of the Mogul dynasty and, in more modern times, some of the largest engineering works which British enterprise has undertaken.

Other examples of the use of sandstones include those of Gondwana age in restricted areas of Bengal, Bihar and Orissa, the Central Provinces and Central India. The richly decorated temples of Orissa and of Chanda are built of them. Sandstones of Jurassic age are plentiful and extensively used in Cutch. In the coastal regions of the extreme south, particularly in Tinnevely district, Madras, ancient Hindu temples and modern Christian churches are constructed of a gritty, calcareous sandstone of sub-recent origin. Quartzites of the Alwar group are quarried in Alwar State itself and in Ajmer-Merwara, Rajputana, while a bedded quartzite of Dharwarian age has been used in the Bhandara district, Central Provinces.

The Purple sandstones at the base of the Salt Range Cambrian and the overlying Magnesian sandstone have both supplied large quantities of stone for buildings and canal works, respectively, in the Jhelum district, Punjab.

Perhaps the most widely known building material of the calcareous group of rocks is the famous 'Porbandar stone', so much used in Bombay, Karachi and elsewhere. It is a fine-grained white or buff limestone consisting chiefly of foraminiferal tests cemented by calcite, with a few oolitic granules and mineral fragments. It is of æolian origin and is quarried along the western base of the Barda hills in Kathiawar. In the Narbada valley the coralline limestones of the Bagh beds (Cretaceous age) supply a useful stone. The town of Jaisalmer in Rajputana is built of limestone of Jurassic age quarried on a large scale in the vicinity. The Narji limestone, from the lower part of the second stage of the Kurnool series of Southern India, is the principal building material of the Cuddapah district and is also widely employed in the Kurnool and Guntur districts, Madras. The stone is very compact, extremely fine-grained and from bluish-grey to black in colour. It has been incorporated in parts of the buildings of the University of Madras. It is interesting to note that the Kurnool formation of Southern India from which this stone is derived is possibly an equivalent in time of the Lower Vindhyan further to the north. Amongst other limestones of economic importance are the Cretaceous ones utilized for buildings at Quetta in Baluchistan, and the banded nummulitic varieties which occur on the Salt range plateau in the Punjab and have been quarried for ornamental purposes. A dark bluish limestone of doubtful Lower Vindhyan age is quarried extensively at Sikosa, Drug district, Central

Provinces and is used for flooring in Nagpur. The Pem limestones of Cuddapah age in the Chanda district are worked at Kandara in the same province.

The occurrences of marble and of limestone quarried for lime-burning are treated separately.

During the years 1923-24 to 1927-28 the value of building and engineering materials imported into India from foreign countries had an average annual value of Rs. 1,22,78,560, exclusive of stone and marble, which averaged Rs. 7,40,221 during the same period. For the previous quinquennium (1919-23), the corresponding figures were somewhat higher, being Rs. 1,82,70,780 and Rs. 8,17,817 respectively. The substances included under the general heading include asphalt, bricks and tiles, cement, chalk and lime, clay and earthenware piping, sanitary ware, etc. For the five years ending 1932-33, the corresponding figures were Rs. 1,39,25,765 and Rs. 5,33,924 respectively.

### BRICK AND TILE CLAYS

The common sun-dried or open-burnt brick, often of a most inferior quality, which supplies the needs of the peasantry, is usually made from the earths used by the village potter for his hollow-ware or country roofing tiles. Selected alluvial clays and silts, found in the neighbourhood of most of the rivers, furnish materials for good bricks, and around the larger cities with their greater and more stringent requirements, brick manufacture is practised on a larger and more up-to-date scale. In 1881, when V. Ball published his *Economic Geology*, the largest brickfield in India was situated at Akra near Calcutta. It was the property of Government and had an outturn of 20 to 30 million bricks annually. Similarly, until it was closed a few years ago, the biggest brickfield in Burma, again the property of Government, lay just outside Rangoon, where clays of Irrawaddian age were excavated mechanically and machine-made bricks produced in great numbers.

The raw material of the numerous brickfields which exist up and down the Hooghly and along its channels and backwaters today, are the old argillaceous deposits of the river itself or the newly deposited silt collected seasonally at the floods. Bricks, roofing tiles, both of the flat and lock pattern, domestic pottery of various descriptions, and the hollow tiles used in the steel-framed structures of Calcutta, are all

made on a large scale and find a ready market in the city and its environs.

*Mangalore Tiles.* The well-known Mangalore tiles of Southern India are also made from water-borne material, and there are many works with revolving presses, specially designed dryers and the most modern form of continuous kilns, centred around Mangalore, Calicut, Palghat and other places on and near the Malabar coast, where, in 1933, there were 52 tile factories under the supervision of the Indian Factories Act. Locked tiles of the Marseilles pattern are the speciality of this industry, but bricks, pipes and various types of pottery are made as well. The exports of tiles from the Madras Presidency for the past decade are given in the following table.

TABLE XVII  
EXPORTS OF TILES FROM THE MADRAS PRESIDENCY

YEAR	FOREIGN EXPORTS		COASTWISE EXPORTS		ANNUAL AVERAGE	
	Number of Tiles	Value	Number of Tiles	Value	Number of Tiles	Value
1923-24 to 1927-28	34,581,288	Rs. 17,56,817	202,605,450	Rs. 96,82,068	47,437,347	Rs. 22,87,777
1928-29 to 1932-33	40,766,407	22,71,925	197,053,447	82,22,295	47,563,970	20,98,844

The average number of tiles exported from the whole of India to foreign countries for the five years ending 1931-32 was 8,630,839, valued at Rs. 4,70,515, over 99.7 per cent of which came from Madras Presidency alone. The principal purchasing countries were Ceylon, Malaya and Kenya Colony.

The silts from which the tiles are formed come from the alluvial deposits near the mouths of the rivers, the Bey pore river supplying the factories of Calicut. Considerable experience is needed in mixing the various grades of clay, which are afterwards ground and pugged into blocks to be 'soured', or stored in large vats for one or two months until the material is plastic, yet tough enough, for its later milling and pressing.

A steady local demand exists, for the use of the lock tile as a roofing material is general in this part of India, and in addition there

is a large export trade, vast quantities being at one time exported to Australia. The tiles, which are excellent in appearance and finish, are in general use in Madras, Bombay and parts of Ceylon and Burma.

*Raniganj Vitreous Tiles.* A somewhat bigger red, vitreous, lock-pattern, roofing tile is made on a large scale at the Durgapur brick and tile works of Messrs Burn & Co. Ltd., on the Raniganj coalfield. These operations commenced in 1900, and in 1921 a modern factory capable of extension for a production of 50,000 tiles daily was erected. The works are stated to be the only ones in India manufacturing vitreous tiles and bricks from a clay with the low vitrification point of under 1,000° C. The kilns operate on the same principles as those in use on the Malabar coast. The clays are red, white or cream-coloured materials included in the sandstones of the Durgapur beds of the Raniganj coalfield, which are of post-Panchet age. In the existing pit near the works, they have a thickness of about 18 feet and it has been suggested that the upper parts may be related to the laterites of the neighbourhood.

In spite of the large quantities of tiles of various descriptions now made in India, the import trade in such materials is still an extensive one, and for the five years ending 1932-33, had an average annual value of Rs. 16,84,424. Italy, France, Belgium and of later years Japan, are the countries mainly concerned in it.

*Special Bricks.* In addition to roofing and flooring tiles and other similar products, machine-made, wire-cut bricks for engineering purposes are produced on a large scale from the same Durgapur clays and are used for heavy foundation works, building and floorings. Millions of these bricks, states Bates, have been used in the construction of the works of the Tata Iron & Steel Co., the Indian Iron & Steel Co., and other heavy industrial concerns. They compare favourably with engineering bricks in use in other countries. Blue facing bricks, equal in quality to the Staffordshire blue brick, were made in large quantities for use in the construction of the King George V Docks, at Calcutta, from mixtures of the local clays of south-western Bengal, by Messrs Burn & Co. and the Bengal Fire-brick Syndicate of Kulti.

Terracotta facing bricks for ornamental purposes are also made from the Durgapur clays and they decorate many of the older public buildings in Calcutta and other cities.

The following table illustrates the composition of some typical Indian clays of low fusibility used in brick manufacture:

ANALYSES OF CLAYS OF LOW FUSIBILITY

LOCALITY	SILICA	ALU-MINA	FER-RIC OXIDE	LIME	MAG-NESIA	ALKA-LIS	LOSS	AUTHORITY
Raniganj ...	62.22	24.42	2.44	1.20	0.44	0.27	9.16	Bates
Durgapur ...	61.70	22.89	6.61	0.54	0.62	1.20	6.52	„
Jubbulpore ...	60.56	27.52	1.44	0.65	0.14	0.60	9.32	„

## CEMENT

Although the cement industry really commenced on a large scale in India in 1914, it is to be noted as a matter of historical interest that small quantities of the material had been manufactured in Madras for ten years previously, and that sea-shells formed the source of the calcium carbonate. The Indian Cement Co. Ltd. started operations at Porbandar, Kathiawar, in 1914 and the growth of the industry since that time has been rapid. In 1923, in the first edition of this book, in addition to the Porbandar concern, factories at Katni, Central Provinces (inaugurated in 1915), and Bundi, Rajputana (1916), were mentioned. Since that time additional works have been erected at Dwarka, Kathiawar (1922); Japla, Bihar (1922); Mehgaon, Central Provinces (1922); Banmore, Gwalior (1923); Wah, Punjab (1923); Kymore, Central Provinces (1923) and Shahabad, Hyderabad (1925). In 1920 the production of Indian cement was 91,253 tons and the imports 155,480 tons; but in 1930, 563,929 tons were made in India alone. The consumption of cement actually increased from a little more than one-quarter of a million tons to over 600,000 tons in a decade. The imports for the period 1928-29 to 1932-33 averaged 110,610 tons, valued at Rs. 51,77,115 yearly. The total capacity of the ten existing Indian plants appears to be in the neighbourhood of 900,000 tons per annum.

The chief raw materials required for the manufacture of Portland cement are limestone and clay, and together they should contain about 75 per cent of calcium carbonate and 25 per cent of clayey matter. They are pulverized in suitable mills to ensure intimate



mixture and are then burnt at very high temperatures in kilns or rotary furnaces. The latter are long steel tubes, 8 or 10 feet in diameter, lined with fire bricks and 100 to 250 feet in length, into which the mixture is fed and calcined by the heat of burning gases from powdered coal. The burnt product, known as 'clinker', passes out of the kiln, and after cooling and mixing with small quantities of gypsum, to correct the speed of the 'setting' of the finished article, is reduced in ball and tube mills to the fine powdered form in which it appears on the market.

As the following notes on the raw materials used at some of the factories in India show, the limestone itself often contains as an original constituent, a certain proportion of clayey matter, and in such cases the amount of clay to be added to the primary mixture is lessened. Strict analytical control of the raw materials and of the product through all its stages of manufacture in the various works, have led to the high reputation which Indian Portland cement now enjoys in the market.

The Indian Cement Co. Ltd., at Porbandar, Kathiawar, uses the pure miliolite limestone of sub-recent, æolian origin, known as 'Porbandar stone', while the silica content of the local clay is improved by the addition of a powdered granophyre from the Barda hills.

The Katni Cement and Industrial Co. Ltd., with its works at Tikuri, about two miles south of Katni, Jubbulpore district, Central Provinces, makes use of dark grey, flaggy limestones of Lower Vindhyan age from quarries near the factory. The rock contains from 80 to 90 per cent of calcium carbonate. The clay comes from the overburden above the limestone, and only a small proportion is required. The gypsum is obtained from Khewra in the Salt range.

At the works of the Bundi Portland Cement Co. Ltd., Lakheri, Bundi State, Rajputana, argillaceous limestone bands from the Lower Bhandar group of the Upper Vindhyan are utilized. These contain from 15.68 to 17.85 per cent of silica; 42.11 to 43.71 per cent of lime; and 3.01 to 3.86 per cent of alumina. The use of clay with such a material is unnecessary as the correct proportions of lime, silica and alumina can be obtained by blending varieties of the limestone. Gypsum is obtained from Jodhpur and elsewhere.

The Sone Valley Portland Cement Co. Ltd., at its works at Japla in the Palamau district of Bihar and Orissa, uses the Lower Vindhyan

limestones from the slopes of the Kymore hills at Rohtas, five miles away, and shales from Daltonganj, about 50 miles distant.

The United Cement Company of India Ltd., with its factory at Mehgaon, near Jukehi, ten miles from Katni, and the Central Provinces Portland Cement Co. Ltd. at Kymore, also ten miles from Katni, utilize limestones of the Lower Vindhya from quarries close at hand. In the first case about 1.6 tons of limestone and a small proportion of clay are burnt to produce 1 ton of cement. In the latter, 1.5 tons of limestone, 0.45 tons of clay and 0.045 tons of gypsum are used.

Banmore, twelve miles north of Gwalior City, is the site of the factory of the Gwalior Cement Co. Ltd. The limestone, to which only a very little clay has to be added, is close to the works.

The Punjab Portland Cement Co. Ltd., at Wah, near Hassan-Abdal, 35 miles north of Rawalpindi, uses a black nummulitic limestone, containing up to 98 per cent calcium carbonate. Small hills of this rock lie close to the site, while alluvial clay is obtained from the lower ground. The gypsum comes from Khewra.

In 1931, several companies commenced the manufacture of rapid hardening cements for which there is likely to be an increasing demand. Most of the companies belong to a central marketing organization known as The Cement Marketing Company of India Ltd.

The uses of cement and of concrete of which it forms an integral part are rapidly expanding in India, not only for heavy constructional work such as roads, bridges, factories, warehouses, wharfs and jetties, dams, reservoirs and retaining walls but also for ornamental details of buildings, frames and mouldings, pipes, hollow blocks and beams, and for many other purposes. With the expansion of industrial and engineering activities, a prosperous future seems assured to the cement industry. It is noteworthy that no cement factory has yet been erected in Burma.

## LIMESTONE

Limestone used for constructional purposes and for cement manufacture, and marble as an ornamental stone, have been considered separately. Limestone (including dolomite), however, is also employed on a large scale as a source of lime and as a flux in the smelting of iron and lead ores. For the five years ending 1928, the average annual recorded production of limestone, including *kankar*, for the

whole of India was 3,083,000 tons, valued at Rs. 50,43,000 and for the five years ending 1933, the average annual amount was 2,936,000 tons, valued at Rs. 40,55,000; or omitting *kankar*, 2,327,294 tons. Of this total of 2,327,294 tons of limestone, Bihar and Orissa furnished 32 per cent, the Central Provinces 18·5 per cent, the Punjab 12·8 per cent, Burma 13 per cent, Rajputana 8·3 per cent, and Central India 5·3 per cent. The remaining 10·1 per cent came from various other provinces.

The earliest reference to the quarrying of the limestones of Lower Vindhyan age at Rohtasgarh, in the Shahabad district of Bihar and Orissa, dates from 1847, and in 1869 Mallet described how it was quarried and burnt there, supplying the surrounding districts extensively, being brought down the Son river in boats and thence up and down the Ganges. Today several companies operate near Rohtasgarh and Dehri-on-Son, while at Japla cement is made from the stone. The Cuddapah formation supplies the limestone quarried near Bisra and Rourkela in Gangpur State. Limestones and dolomites of Dharwarian age also occur further north in the same State, the producing quarries being in the neighbourhood of Raipura. The requirements of the Tata Iron & Steel Co. Ltd. are met from this region.

In the Central Provinces, the Lower Vindhyan are again the source of the limestone quarried on a large scale for many years at Katni, Jubbulpore district. This stone is also used for cement manufacture.

The Punjab production comes mainly from the Attock, Jhelum and Rawalpindi districts.

There is but little limestone in Central Burma. A nummulitic variety near Tondaung in Thayetmyo and a coral reef of Pegu age at Maukthayet, in the Lower Chindwin district, support local industries. In the Palæozoic limestones of Tenasserim and the Shan States and the Archæan limestones of Upper Burma, however, there are inexhaustible supplies which are drawn on extensively in conveniently situated parts of the Amherst, Meiktila, Mandalay and Sagaing districts as well as in the Shan States. In the latter territory Jurassic limestones are quarried near Nam Tu, by the Burma Corporation Ltd., for use in lead smelting.

Rajputana limestones come mainly from the States of Bundi, Jodhpur and Sirohi. Certain beds of the Lower Bhandar (the

uppermost series in the Vindhyan system) in Bundi, are well suited for lime-burning and are used in the manufacture of cement in addition. Vindhyan limestones also occur in inexhaustible quantities in the vicinity of Sojat, Bilara and Gotan in Jodhpur, where A. M. Heron (1935) reports a thriving lime-burning industry supplying local needs and sending lime by rail as far as Gujarat. In Sirohi, according to A. L. Coulson, the grey Delhi limestone, north of Abu Road, supplies ballast to the railway and lime which is sent as far afield as Ahmedabad, Palanpur and Ajmer. Abundant supplies of *kankar*, however, are easily available and are preferred as a local source of lime to the less pure though more abundant calcareous rocks.

The more important centres in Central India are in the Rewah and Maihar States, where the limestone is won from the Upper Vindhyan formation. Some of this stone is said to be railed to Bengal for use in the iron-smelting industry there.

Nunimulitic limestones from the southern scarps of the Khasi and Jaintia hills are used for lime-burning in Assam.

*Kankar* is a vernacular term applied to the small irregular concretions of carbonate of lime, which are widespread throughout the alluvial deposits of India and Burma, particularly in the older alluvium. Occasionally it segregates into more or less ill-defined beds and it frequently fills cracks in the surface deposits. The administration of the United Provinces appears to be the only one which regularly reports the production of *kankar* separately from its areas, and the amounts so recorded have averaged 609,000 tons per annum for the five years ending 1933. It is widely used as a road dressing and is sometimes burnt for lime.

## MARBLE

'Amongst the remains found on the Mohenjo-Daro site in the Larkhana district of Sind,' writes Sir Edwin Pascoe, 'were shaped and dressed blocks of polished marble, many of them evidently for building purposes. The stone resembles that from Makrana in Rajputana, whence we may imagine it to have been carried across the desert to the ancient city. Associated with these shaped blocks were found seals bearing a script having many resemblances to the Sumerian script of Mesopotamia. The marble quarries of north-western India, therefore, appear to have an antiquity which it would be difficult to rival.'

The Makrana quarries are in the Jodhpur State and are believed to have supplied the stone for the Taj Mahal at Agra, which was erected by the Emperor Shah Jahan (1628-58) as a mausoleum to his wife, Mumtaz Mahal, and which is considered by many competent authorities to be one of the most beautiful and perfect structures in the world. The Victoria Memorial in Calcutta was constructed of the same stone. Many of the Rajputana States contain deposits of marble of varying degrees of grain, hardness and colour, occurring in both the Aravalli and Delhi systems. 'Almost everywhere in the extensive area occupied by its outcrops in North-Eastern Rajputana,' writes A. M. Heron, 'the Raialo limestone—which passes up conformably into the lowest bed of the Alwar series—affords good marble, quarried chiefly in the vicinity of Raialo, in Jaipur; and of Jhiri, in Alwar. The stone is an excellent, pure white, saccharoidal marble.' Pink, pale grey and black varieties also occur. White marble from another limestone band in the same series of rocks is quarried at Dadikar, in Alwar, while a handsome modification of the Kushalgarh limestone forms a narrow-banded, black-and-white variety near Badgaon and close to the Alwar-Jaipur boundary. Again, the Rajnagar marble, a pure white stone, quite free from grey cloudiness, is exposed over wide areas around Nathdwara in Udaipur State. It has supplied vast quantities for embankments, palaces and temples, but the amount available is literally inexhaustible. Marbles from Rajputana, as well as suitable kinds of Vindhyan sandstones, were used for the preparation of the open-work screens which are such striking features in the internal decoration of many historic buildings in India. 'Their delicate tracery, fretted into an almost endless network of geometrical combinations, is so minutely pierced that they look like lace from a distance.'

'It is to be remembered', wrote Dr Heron in 1935, 'that the marbles of Rajputana, such as those quarried at Makrana, Rajnagar and Raialo, have important local uses as building stone for ordinary village houses, as well as their export as ornamental stone. A dilapidated village built of white marble and mud appears incongruous, but the available supply of marble is probably much in excess of any possible export and there is always an abundance of inferior stone which cannot find an outside market.'

Little use has been made generally of the marble deposits which occur in other parts of India. In the Coimbatore district of Madras, vast quantities of greyish-white and flesh-coloured stone occur, while

the Chitaldroog and Mysore districts of Mysore State contain further supplies of the former. Other deposits are known in the Salem, Madura and Tinnevely districts. The Archæan formations of the Central Provinces have the 'Marble Rocks' in the Jubbulpore district, and numerous excellent marbles have been found in the Betul, Chhindwara, Nagpur and Seoni districts. The beautifully marked, serpentinous varieties of the Sausar tehsil, in the Chhindwara district, deserve especial mention.

The Sagyin hills, north of Mandalay in Burma, are to a great extent composed of white marble, from which most of the images of the Buddha—some of them of colossal size—which repose in the innumerable pagodas of the country, have been carved. Marble also occurs in the Kyaukse district, and the great masses and bands of the Ruby Mines region, in Katha, have their counterpart in the frontier ranges of the Bhamo district, between Burma and China.

Black and white marbles are said to be worked in the Mandi and Datla hills of Patiala State in the Punjab, and a white stone used to be quarried at the State Marble Works, some eight miles from Narnaul railway station.

D. N. Wadia has recently described snow-white massive marbles in bedded aggregates, up to 600 feet in thickness, in the Kunhar valley, Hazara district, North-West Frontier Province, but the locality is not easily accessible.

Unusual varieties include the lovely green, pink and white, mottled stone from Harikua and its handsome brecciated relative from Sandara in Baroda; the black marbles of Rewa Kantha, Bombay; the pale green, or dark green and yellowish, clouded marble of the Kurnool district, Madras; the onyx marbles of the Shahpur district, Punjab; the coral-line varieties of the Lower Narbada valley, employed in building many ancient temples, mosques and palaces and remarkable for their thick bunches of branching bryozoa; the homogeneous yellow marble, and the yellow and grey, shelly kinds of Jaisalmer in Rajputana; and, finally, the semi-sacred 'Abur Stone', a dark red, fossiliferous marble in which the fossils have been changed into a yellow substance.

The average annual production of marble for the five years ending 1928 was 5,354 tons, valued at Rs. 1,48,894, of which 80 per cent came from Jodhpur and the remainder from Alwar and Jaisalmer. The average annual production for the four years ending 1932 was 4,830 tons, valued at Rs. 1,76,110.

The cost of transporting the marbles of Rajputana by railway to the great cities of India, such as Bombay, Calcutta or Madras, hinders the large scale development of the quarries, and there is an extensive trade in imported material, chiefly from Italy and Greece. In normal times the imports of 'stone and marble' have an average annual value of between Rs. 7 and 8 lakhs.

### SLATE

Slates are quarried at many places in the outer Himalayas of Kumaon, Garhwal, Kangra and Chamba, and good roofing materials are obtainable locally for the hill towns and villages. The slates of the southern flanks of the Dhauladhar range were known to be of first-rate quality as early as 1860, and according to H. B. Medlicott, the fissility of the material is all that need be desired; it dresses easily and can be procured in ample sizes. It is a nearly pure siliceous rock of pale grey colour but, at the same time, not so fine in its minute texture as ordinary Welsh slate; it is therefore not applicable to some purposes for which the latter is used. Several companies quarry slate in the Kangra district at the present time. D. P. Chandoke has published an account of slate quarrying around Dharamsala, Kangra district (1933), and states that the slates are derived from rocks of infra-Krol age, being grey or black in colour, not very fine in texture, siliceous, slightly carbonaceous and calcareous and yielding a sonorous ring when struck. They possess all the qualities required in a good roofing material, that is to say a straight, uniform and smooth cleavage, an attractive colour of an unfading character and an absence of mineral constituents which dissolve with relative ease.

The Ajabgarh series of rocks which lies at the top of the Delhi system of Purana age, in north-eastern Rajputana and adjoining areas, yields slates which are quarried in the vicinity of Rewari, Gurgaon district, Punjab. A. M. Heron states that they are really hardened shales rather than true slates. Frequently there are thin films of iron oxide along the bedding planes, which render the slabs difficult to cut and cause them to wear unevenly, but the Kangra Valley Co. has for several years been working an excellent band at Kund, free from this defect and giving smooth, fissile, even-coloured and textured slabs. The slates are obtainable in all sizes, and roofing material down to one-eighth inch thickness is cut. On the same strike inferior qualities are worked at Mandan, in Alwar State, Rajputana.

The slates of the Kharakpur hills, Monghyr district, Bihar, have been known from the middle of the nineteenth century and were probably worked on an extensive scale much earlier. The rock is a slightly metamorphosed phyllite, probably of Dharwarian age, which is readily fissile with the plains of lamination. It does not give the best varieties of roofing slate, but fine slabs are procurable which are used for particular kinds of roofing, flooring and electrical purposes.

Slates are also obtained from Singhbhum, Bihar, and many occurrences have been noted from time to time in other parts of India and in various divisions of the older rocks, including the Cuddapahs of the district of the same name in Madras, the Champaner beds of Baroda, the Kaladgi series of Bijapur district, Bombay, and the Bijawar series in Gwalior, Central India.

The present production of slate from the Punjab ranges between 5,000 and 6,000 tons per annum, while the recorded annual average production from the whole of India for the three years ending 1933 was 9,475 tons, valued at Rs. 1,89,178.

## GYPSUM

Gypsum, the hydrous calcium sulphate ( $\text{CaSO}_4, 2\text{H}_2\text{O}$ ), is known as selenite when it occurs in a transparent, crystalline form; its massive, fine-grained modification is alabaster; while the commonest variety is the ordinary bedded rock gypsum.

The production of gypsum is increasing in India, as the following table shows:

TABLE XVIII  
PRODUCTION OF GYPSUM

PERIOD	AVERAGE ANNUAL PRODUCTION	VALUE
	<i>Tons</i>	<i>Rs.</i>
1914-18 ...	18,857	14,625
1919-23 ...	35,133	45,407
1924-28 ...	41,199	93,937
1929-33 ...	50,112	98,017

During the five years ending 1933, approximately 70 per cent of the output was derived from Rajputana, 27 per cent from the Punjab, and the remainder in small amounts from Kashmir, Madras and elsewhere. Of the Rajputana production 54 per cent was contributed



by the Bikaner State, 45 per cent by Jodhpur and the remainder came from Jaisalmer. The total Indian output of gypsum for 1934 was 46,757 tons.

Gypsum beds of some thickness occur at several places in the Great Indian desert, especially on sunken areas surrounded by sand-hills and once occupied by salt lakes. It is presumed in the absence of more definite information that the Nagaur deposit in Jodhpur and the Jamsar one in Bikaner belong to this type. In the Jhelum district of the Punjab the mineral occurs in enormous quantities, both as selenite crystals and as massive beds associated with the Salt Marl, and extending further through the Shahpur and Mianwali districts along the whole length of the southern flank of the range, from Jalalpur to Kalabagh on the Indus. It is mainly developed in the upper part of the marl and as a rule underlies the salt. At Khewra, in the Jhelum district, gypsum is quarried as a subsidiary industry by the Department of Northern India Salt Revenue. Other Punjab occurrences include beds reaching two or three feet in thickness, in the Lower Chharat stage of Nummulitic age in Attock and Rawalpindi.

The Kashmir deposits are also very large and lie along a line of country which stretches for 15 miles, to the north of the Jhelum valley cart road, near Braripara in the Urie tehsil.

Gypsum is common in many parts of the Cretaceous rocks of the Trichinopoly district, Madras, where, according to H. F. Blanford, it is most abundant in the Utatur beds and especially in the Belemnite clays to the east of Utatur itself, generally in the form of fibrous plates interbedded in the rock.

Only a selection of the remaining important occurrences can be mentioned here. Immense amounts exist in the trans-Indus Salt region of the Kohat district, North-West Frontier Province, in the upper portion of the Eocene Nummulitic series, where more or less continuous masses up to 200 feet in thickness are found with bands of shale and clay. Huge deposits also occur in Spiti and Kanaur, in the Punjab Himalayas, where the mineral has been formed by the replacement of Carboniferous limestones through the action of hot, sulphurous spring waters.

Shales of Jurassic, Cretaceous and Tertiary ages in Cutch, Kathiawar and Sind are known to contain large quantities, and it is a characteristic mineral of the Tertiary clays and shales of Burma and

Baluchistan, usually as thin laminæ following bedding planes, or as narrow veinlets in cracks and joint planes, the scattered character of which, at any rate in the former province, prevents its commercial exploitation. Thick beds are, however, reported from the Eocene shales of the Bugti and Marri hills in Baluchistan.

Sir Edwin Pascoe states that the massive gypsum deposits of north-western India are nearly always accompanied by highly ferruginous beds which are believed to denote subaerial and probably arid conditions of formation. There is little doubt that such deposits of the mineral were derived originally from sea water, trapped in dessicating, land-locked lagoons and shallow arms of the sea.

On moderate heating, gypsum parts with some of its water of crystallization and forms the quick-setting cement known as plaster of Paris, so invaluable for taking casts, which is also used to give a hard finish to the interior walls of buildings. When raised to a higher temperature, gypsum becomes almost anhydrous though still retaining its quick-setting properties. In this condition it forms the basis of various patent plasters, fire-proofing materials and the plaster boards, of which the manufacture is rapidly increasing in the United Kingdom. Pure ground gypsum is known as 'mineral white' or 'terra alba', and finds applications as a filler in the paper and rubber trades, in the preparation of certain kinds of paint and in the cotton industry. Gypsum is also an excellent 'top dressing' for some types of land. Wynne, in 1875, noticed that the crops and particularly the wheatfields of the Kohat region grew better on the soils of the gypseous clays than elsewhere, though he remarked that the advantages to be derived from its use were apparently entirely unknown and the mineral was utterly neglected, a charge no longer true of the country as a whole. Gypsum is also absorbed in increasing amounts in India by the cement industry in which it is employed as an agent to control the setting time of the finished product. The quantity usually employed for this purpose appears to be about two or three per cent. When it is realized that the recorded world's production of gypsum now reaches about twelve million tons per annum, the important part played by the mineral in industry generally is better appreciated.

## CHAPTER VIII

### REFRACTORIES, CERAMIC AND GLASSMAKING MATERIALS: POTTERY EARTHS AND CLAYS, CHINA CLAYS, FELSPAR, QUARTZ, FIRE- CLAYS, SILICA BRICKS, MAGNESITE, SILLIMANITE, KYANITE, ZIRCON, GRAPHITE AND GLASS SANDS

#### POTTERY EARTHS AND CLAYS

THE potters constitute one of the great functional castes of the Hindu social system, and their coarse, unglazed products are to be seen everywhere. Any local earth, often from the neighbourhood of the village tank, containing sufficient iron and lime to make it fusible at moderate temperatures, suffices to fashion the earthenware cooking pots, water jars, roofing tiles and the numerous small articles which are moulded on the wheel, dried in the sun and burnt, often in the courtyard adjoining the potter's dwelling. 'As a substitute for glaze on ordinary ware,' states V. Ball, 'mixtures of fine clays which adhere after heating are sometimes used, but they are rather in the nature of paints than true glazes, being soft and easily scratched with a pin.' Much of the prehistoric pottery of India of red, black, brown or cream tints, has a shining, unglazed surface and is far superior in workmanship and design to the common forms of the present-day ware. Better quality wares are of course made for special or ornamental purposes. These include the red earthenwares of Hyderabad and Travancore, the red glazed pottery of Dinapore and the black ware of Monghyr, Chunar and Azimgarh. An earth from Moghal Sarai in the United Provinces contains fine mica and is said to yield a very porous ware which is used in the manufacture of pitchers. The tenacious clays of the Tertiary rocks of Burma supply material for the large Pegu jars, often three or four feet high, which are a speciality of Salingyi in the Lower Chindwin valley, of villages near Kyaungmyaung in Shwebo district and elsewhere, whence they are floated in 'rafts' down the

Irrawaddy even as far as the deltaic districts. The red and black, polished and incised earthenware of Mong-Kung in the Federated Shan States, has a wide repute and is distributed to far distant places.

*Salt-Glazed Stoneware.* Clays of low fusibility are used on a large scale in modern potteries in India for the manufacture of salt-glazed stoneware such as drain pipes and fittings, non-porous roofing tiles, sanitary ware and domestic utensils of better quality than those turned out by the village potter. Such articles, states W. H. Bates, a leading Indian authority on these subjects, require a vitrified or partially vitrified, tough and non-absorbent body under the glaze. The principal potteries concerned are those of Messrs Burn & Co. Ltd. at Raniganj in Bengal, founded in 1859, and those of the same firm at Jubbulpore in the Central Provinces which started operations in 1890; the Perfect Pottery Co. Ltd., also of Jubbulpore, and the Katni Pipe Works of the Katni Cement and Industrial Co. Ltd., Central Provinces. Bates estimates that the four works mentioned are together capable of producing 30,000 tons of sanitary, salt-glazed ware per annum, equal to 1,500 miles of 4-inch diameter pipes each two feet in length. Stoneware, salt-glazed pipes are also made by the Kumardhubi Fire-Brick and Silica Works Ltd. and by the Bengal Fire-Brick Co., both of which operate on the Raniganj coalfield.

The raw material used at Raniganj is a dark grey, carbonaceous clay, occurring as a nearly flat seam, three or four feet in thickness, near Ronei. E. R. Gee considers that it is an impure fire-clay included within the upper part of the Raniganj coal measures. The light grey clays quarried in the past to the north and east of Ronei, are either weathered outcrops of argillaceous bands of the same measures, or directly associated with the overlying laterite. After excavation, the clays are stored for three years, blended with others and mixed with certain chemicals before use.

The Jubbulpore works use the white or pale grey clays which are interstratified with soft white sandstones of Upper Gondwana age and which attain their greatest development, both vertically and superficially, in the vicinity of Chota Simla. The beds in both cases are said to be irregular in quality and the material from any particular seam is rarely used alone; sand, felspar, quartz and other minerals

being freely added to the mixtures under the directions of the chemists of the works concerned.

Indian salt-glazed ware is made to British standard specifications, and the fact that great cities like Calcutta and Madras use it entirely in their sewerage systems, is sufficient testimony to its quality. Exports reach Burma, Ceylon and Malaya.

The average annual values of the imports of some kinds of foreign earthenware reaching India are given in Table XX (page 186).

## CHINA CLAYS

India never attained the higher branches of the potter's art reached in some other eastern lands, and V. Ball's statement written in 1880, that there is probably no part of the world, not excluding remote oceanic islands, where the use of glazed pottery is less known than is the case in many parts of India, was doubtless true enough at that time. The principal varieties of artistic pottery made in the country were summarized by Sir George Birdwood as follows: 'The red glazed pottery of Dinapore, the black and silvery pottery of Azimgarh in the North-West Province and Surajgurha (Bhagalpur) in Bengal, the imitation *bidri* of Patna and Surat in Gujerat, the painted pottery of Kota in Rajputana, the gilt pottery of Amroha, also in Rajputana, the glazed and unglazed pressed pottery of Madura, and the glazed pottery of Sindh and the Punjab.'

In 1839, the authorities of the East India Company, alarmed at the expense of supplying wares from Europe, directed that attempts should be made to procure efficient substitutes in India, and various clays from Colgong, Rohtasgarh, Moulinein, Madras and Singapore were tested in the laboratory of the Medical College in Calcutta and experiments made in glazing them. There are records of potteries at Fatehgarh, Farrukhabad district, United Provinces about this time, where tableware and glazed tiles were made in addition to more ordinary stoneware. Another pottery was operated between 1860 and 1864, at Patarghatta, in the Bhagalpur district of Bihar and Orissa, where chinawares and porcelain for scientific purposes are said to have been made.

In more recent times, at the beginning of the present century, the Bengal Potteries Ltd. of Calcutta had succeeded in producing cups, saucers, jugs and ornaments of common white porcelain, using kaolin from Mangal Hat in the Rajmahal hills. This concern is the largest

of its kind in India today, and other works using china clay in the manufacture of white ware and porcelain include, Messrs Burn & Co. Ltd., Raniganj; the Gwalior Potteries Ltd., with factories at Gwalior and Delhi; the Chunar Potteries in the Mirzapur district, United Provinces; the Than Pottery in Kathiawar; and the Mysore Government's works at Bangalore. Details of the processes adopted have recently been given by W. H. Bates, whose account closes with the following remarks: 'With the exception of insulators (made in large quantities at the Calcutta potteries and used principally by the Telegraph Department), the china clay and porcelain products of Indian works cannot on the whole justly be regarded as being equal to the imported European ware, and especially to the best English sanitary ware or domestic crockery. This can be understood by those who know the years of training necessary for workers to acquire the proper methods. There is a steady improvement in the products made in India and it is a matter of time only when these goods will be equal to the best made in other countries.'

References to deposits of china clay and kaolin abound in Indian geological literature, and only a few selected ones can be mentioned here. Although the two substances are generally grouped together and although kaolin forms the greater part of such clays, few of them have the exact chemical composition of the mineral species, and potters, finding from experience that some so-called china clays are unsuitable for their particular purposes, usually separate the two, so that although any white-burning clay may be a 'china clay', a true 'kaolin' must possess a high refractory index and should not show signs of vitrification under a temperature of  $1750^{\circ}\text{C}$ . The white, compact, impure kinds of kaolin, known as the 'lithomarges', often found at the base of laterite outcrops in India, are, on the authority of Bates, unsuitable for the purposes for which white clays are mainly used, owing to their lack of suspensibility in water after fine grinding.

In the Rajmahal hills, Santal Parganas, Bihar and Orissa, Murray Stuart found china clay occurring as a decomposition product of felspar in the gneisses and schists, and also in white sandstones of Damuda age, both as disseminations and inter-stratified beds. Important localities of the first type are Katangi, Karanpur and Dodhani. At Mangal Hat the clay is extracted from a sandstone for use in the Calcutta potteries, where it is stated to be 'not in any way inferior to German or Japanese kaolins'. At the Patarghatta locality, a few miles

below Colgong, Bhagalpur district, the quality of the clay is said to be excellent and the supply practically unlimited.

In northern Singhbhum the exploitation of china clay forms a small but thriving industry. J. A. Dunn states that the deposits occur at widely separated points, but all are either in granite or in rocks immediately adjacent to it. They are a result of the kaolinization and frequently of the sericitization of the granite and country rock, perhaps by pneumatolysis but more probably by hydrothermal agencies, just before and after the intrusion and solidification of the granite itself. In another part of the Singhbhum district, a deposit is exploited at Hat-Gamaria, some thirty miles south of Chaibasa. The methods adopted here have been described lately by F. B. Kerridge. The finished product is largely used for paper-filling, whilst a light pink variety has been adopted successfully in the Calcutta potteries for 'stoneware' acid jars. D. P. Chandoke (1932) has described deposits near Manjhapara, in the Gangpur State.

The kaolin mines of Kasumpur, near Delhi, described by Hackett in 1880, Heron in 1925 and Chandoke in 1933, were probably worked in the time of the Mogul emperors, and today supply the needs of the Gwalior potteries. The mineral is obtained from altered pegmatites intrusive into quartzites.

The occurrences of white clays of Upper Gondwana age near Jubbulpore, will be referred to under FIRE-CLAYS. Further supplies, in thicker beds than usual, were reported by Crookshank in 1928 from the neighbourhood of Muria, about sixty miles from Jubbulpore.

The demands of the Government porcelain factory in Mysore are met from deposits at Arjunbettahalli, near Golhalli, Bangalore district, and from Kokkod in the Koppa taluk of Kadur. China clay resulting from the decomposition of granite is won near Yinyein, Thaton district, Burma, while other accessible deposits include one near Castle Rock, Kanara district, Bombay, described by V. Rao in 1926.

For the five years ending 1928, a grand total of 130,250 tons of china clay was produced in India, or an annual average of 26,050 tons, compared with an annual average of 18,156 tons for the four years ending 1932. Of the grand total, 27·3 per cent came from the Jubbulpore district, Central Provinces; 24·6 per cent from Bihar and Orissa; 15·3 per cent from Mysore; 14·8 per cent from the Burdwan district of Bengal; 9·8 per cent from Delhi; and the remaining 8·2

per cent from Central India, Gwalior, Rajputana and Madras. Of the Bihar and Orissa output, half came from Singhbhum, 48 per cent from the Bhagalpur district and the remainder from Seraikela.

The average annual imports of foreign china clay into India drawn almost entirely from the United Kingdom, for the five years ending 1927-28, were 23,216 tons, valued at Rs. 17,95,213, compared with 17,934 tons, valued at Rs. 9,87,552 for the five years ending 1932-33.

The average annual value of the imports of finished porcelain goods for the period 1928-29 to 1932-33, was as follows:

Electrical Porcelain	...	...	Rs. 1,47,267
Other Kinds	...	...	„ 25,06,235
Total Rs.			26,53,502

### ANALYSES OF INDIAN CHINA CLAYS

LOCALITY	ALU- MINA	IRON OXIDE	LIME	MAG- NESIA	ALKA- LIS	WATER	COM- BINED SILICA	INSOL. SILICA
Singhbhum <sup>1</sup>	36.28	0.89	0.86	0.65	...	11.48	44.07	4.88
Patarghatta <sup>2</sup>	36.01	0.27	1.55	0.81	0.82	13.06	47.40	

### FELSPAR AND QUARTZ

The potash felspar, orthoclase, is used in the ceramic industry in the formation of both the body and the glazes of chinaware and porcelain. It is also an important constituent of enamels for coating metal wares, such as kitchen utensils, and it has further applications in the manufacture of glass and as a flux in the formation of abrasive wheels.

Felspar is regularly produced in Rajputana, the average annual output for the five years ending 1934 being 436 tons, valued at Rs. 9.5 per ton. It comes mainly from Ajmer-Merwara, where it is in part a by-product of beryl mining at Taragarh hill, but is also obtained from other localities such as Babugarh hill. Here, according to K. L. Bhola (1935), coarse crystals of pure pink and white microcline up to 20 feet in diameter, occur as pockets in the quartz core of a pegmatite. Smaller quantities have also been recorded from Alwar

<sup>1</sup> Authority: Kerridge. Average of six samples.

<sup>2</sup> Authority: Macdonald. Average of four samples.



State, where the mineral occurs under similar conditions near Khair-tal. Rajputana felspar is used in the potteries of Delhi and Gwalior.

Quartz is obtained as a by-product in felspar mining, and a market for the Rajputana mineral may eventually be found in the glass works of Kathiawar and the United Provinces. Supplies for foundry purposes are taken from veins between Ajmer and Nasirabad, while the glass bangle industry of Agra uses similar material from Dausa in Jaipur State.

Both minerals are mined departmentally in Mysore, to meet the demands of the Government's porcelain factory. Potash felspar, containing about 13 per cent of potassium oxide ( $K_2O$ ), is obtained from a large pegmatite vein at Shettihalli, near Chikbanavar, and white quartz from Peenya near Yeswantpur.

In his description of the mica fields of Bihar, published in 1891, Sir Thomas Holland wrote that if there had been any market for a porcelain industry at that time, an abundance of clear felspar, then being rejected, would have been available in any part of the mica belt, and it is doubtless from some such source that the supplies of the future will be drawn. To be acceptable to the potter, felspar must be free from ferruginous impurities; it should therefore not contain inclusions of coloured minerals like the dark micas, garnets, tourmaline, amphiboles and iron ores. The presence of free quartz in moderation is not objectionable.

## FIRE-CLAYS

The potteries of Messrs Burn & Co. were established at Raniganj in 1859, and before 1875, in addition to their normal activities, fire-bricks had already been produced, for in that year trials of these materials were made in the furnaces of the Calcutta mint where 'several of them stood the test perfectly, showing no sign of cracking or of vitrification'. The Jubbulpore works of the same concern were established in 1890, and as certain of the Upper Gondwana clays utilized there for other purposes are exceedingly refractory, they may be used for the manufacture of fire-bricks as well. For many years fire-bricks made by this company, the only one specializing in this work in India, were supplied for blast furnaces and foundries, settings for gas retorts, the cupolas of railway workshops and for most of the other purposes where high temperatures have to be maintained. As a result of the foundation of the Tata Iron & Steel Works in 1904,

the demand for fire-bricks and other classes of refractory goods rapidly increased, and today there are five other concerns utilizing fire-clays on the Bengal coalfield, in addition to the works already mentioned.

The existing works of Messrs Burn & Co., which were started in 1910, are at Garphalbari and have a capacity of 2,000 tons monthly. Others include the Kumardubhi works of Messrs Bird & Co., which commenced in 1907 and the fire-clay department of which includes machinery for making standard bricks at the rate of 12,000 per day. The kilns comprise one of the regenerative, gas-fired, continuous type with ten chambers, capable of producing 10,000 bricks per day and a battery of eight, beehive, down-draught, coal-fired kilns, each holding 25,000 bricks. The Reliance Fire-Brick Works of Messrs Andrew Yule & Co. at Chanch were completed in 1920. They include sixteen down-draught circular kilns, with a full capacity of, approximately, eight lakhs of standard bricks per month.

The Bengal Fire-Brick Works of Messrs Martin & Co. are situated at Kulti, close to the works of the Bengal Iron Co. Ltd. There are nine kilns of circular, down-draught type, some of which produce 60,000 fire-bricks of various sizes per month. Another type of refractory brick which contains a large percentage of alumina is manufactured here for lining the rotary kilns used in cement works. The works of the Behar Fire-Bricks & Potteries Ltd. (Messrs A. C. Banerjee & Co.), built in 1920 near Mugma, include eight down-draught kilns of 20 to 24 feet internal diameter, capable of producing 500,000 standard bricks per mensem. The maximum combined total output of all the works engaged in the manufacture of these materials in India was estimated recently by W. H. Bates at 100,000 tons per annum or 25 million standard bricks ( $9" \times 4\frac{1}{2}" \times 3"$ ). Most of the works produce other products as well and some of them utilize the rarer refractory minerals for blending or for special purposes.

The clays used on the Raniganj coalfield are of very good quality and are found in numerous seams, up to several feet in thickness, within the lower and middle measures of the Barakar series. E. R. Gee, from whose work these details are taken, states that the principal areas include the outcrops of the Garphalbari-Dahibari grits and coal measures to the north and south of the Kudia *nala*, the equivalent rocks to the south-east of Damagaria, the lower measures of the Radhaballavpur-Shyamdi-Pahargora area, the Ramdhara-Kantapahari

TABLE XIX

## LIST OF WORKS USING INDIAN CLAYS

(Incomplete and mainly as given by W. H. Bates)

CONCERN	PROPRIETORS	PROVINCE	DISTRICT	ARTICLES MANUFACTURED	CLAY USED
...	H. K. Banerjee & Co.	Bengal ...	Dacca ...	Tiles, etc. ...	Local Clays and Silts
actory ...	J. P. Banerjee ...	Bengal ...	Hooghly ...	Bricks and Tiles ...	River Silts
Co. ...	Martin & Co. (A) ...	Bengal ...	Burdwan ...	Fire-Bricks, Pipes, etc. ...	Local Fire-Clays
id. ...	Bengal Potteries Ltd.	Bengal ...	Calcutta ...	Pottery Ware, etc. ...	China Clays ( <i>see text</i> )
y Works ...	Kilburn & Co. (A) ...	Bengal ...	Hooghly ...	Bricks and Tiles ...	River Silts
rks ...	K. B. Roy ...	Bengal ...	Hooghly ...	Tiles and Pottery ...	River Silts
Vorks... ..	Burn & Co. Ltd. ...	Bengal ...	Burdwan ...	Refractory Goods ...	<i>See text</i>
Works ...	Burn & Co. Ltd. ...	Bengal ...	Burdwan ...	Stoneware, Pipes, etc. ...	<i>See text</i>
Works ...	Bengal ...	Bengal ...	Hooghly ...	Glazed Earthenware ...	
& Potteries	A. C. Banerjee & Co.	Bihar and Orissa ...	Manbhum ...	Fire-Bricks and Tiles ...	Local Fire-Clays
...	Ltd. ...				
ick Works ...	Burn & Co. Ltd. ...	Bihar and Orissa ...	Manbhum ...	Fire-Bricks and Tiles ...	Local Fire-Clays
Fire-Brick &	Bird & Co. Ltd. (A) ...	Bihar and Orissa ...	Manbhum ...	Fire-Bricks and Silica Goods ...	<i>See text</i>
l. ...					
ck & Pottery	A. Yule & Co. Ltd. (A)	Bihar and Orissa ...	Manbhum ...	Fire-Bricks and Silica Goods ...	<i>See text</i>
...					
Ltd. ...	Gwalior State ...	Central India ...	Gwalior and Delhi	Chinaware and General Pottery	China Clay, etc.
ks Ltd. ...	Delhi Pottery Works	Delhi ...	Delhi ...	Pottery Ware ...	China Clay, etc.
...	Ltd. ...				
Works Ltd.	Burn & Co. Ltd. ...	Central Provinces...	Jubbulpore ...	Fire-Bricks and Stoneware ...	Local Clays
& Industrial	Macdonald & Co. ...	Central Provinces...	Katni ...	Fire-Bricks and Stoneware ...	Local Clays
...					
...	Perfect Pottery Co. Ltd.	Central Provinces...	Jubbulpore ...	Fire-Bricks and Stoneware ...	Local Clays
ns ...		Madras ...	Mangalore ...	Tiles and Bricks ...	River Silts, etc.
ory ...		Travancore ...	Quilon ...	Tiles and Bricks ...	River Silts, etc.
Works ...		Mysore ...	Bangalore ...	Tiles and Fire-Bricks ...	Local Clays
rust Ltd. ...	Commonwealth Trust	Madras ...	Malabar Coast	Tiles and Pottery ...	Silts and Clays
...	Ltd. ...				
Ltd. ...	Madura Co. Ltd. ...	Madras ...	Malabar Coast	Tiles, Pottery and Fire-Bricks...	Silts and Clays
field Ltd. ...	Harrisons and Cross-	Travancore ...	Quilon ...	Tiles, Pottery and Fire-Bricks...	Silts and Clays
...	field Ltd. ...				
Clay Works		Mysore, Madras,	Bangalore, S. Mala-	Tiles, Bricks and Terra-Cotta	River Silts and Local
...		Cochin ...	bar, Alwaye ...	Ware ...	Clays
...					
ain Factory...	Mysore State ...	Mysore ...		Porcelain ...	<i>See text</i>
r Co. Ltd. ...	J. Taylor & Sons (A)	Mysore ...	Kolar ...	Fire-Bricks, etc. ...	Local Clays
is ...	R. M. Vias ...	Rajputana ...	Bikaner ...	Tiles ...	Local Clays
orks ...	Chunar Pottery Works	United Provinces...	Mirzapur ...	Pottery ...	Local Clays
...	Frizzoni & Co. ...	United Provinces...	Cawnpore ...	Tiles, etc. ...	Local Clays

area, the Garh Dhemo-Churulia area and the lower Barakar outcrops of the trans-Adjai region.

The works of the Kolar Brickmaking Co. Ltd., founded in 1917, are on the property of the Mysore Gold Mining Co. Ltd., about sixty miles east of Bangalore in Mysore. Two principal varieties of clay are used from selected localities near Malur, in the Shimoga district, some forty miles away, where they occur beneath a thin lateritic cap and have been proved to be of considerable thickness. From mixtures of these clays, analyses of which are given below, crucibles, muffles, scorifiers, etc., are made for use in the assay departments of the several mines of the Kolar goldfield, while ordinary fire-bricks find a good market in various districts of Southern India. Fire-bricks of special designs are also manufactured for locomotive furnace arches and for cupola linings, the demand for which has steadily increased during the past few years. The bricks do not soften under a temperature of  $1,700^{\circ}$  C., have an after-expansion as low as 0.5 per cent, and have been stated by authorities in the United Kingdom to be 'excellent for any industrial purpose'.

Indian-made refractory bricks have proved equal in strength and durability to the best obtainable in any other country, and the position which they have established for themselves is illustrated by the imports from abroad. For the three years ending 1922 the average number of fire-bricks imported into the country was 2,868,488, with a value of Rs. 9,36,927. Ten years later, for the three fiscal years ending 1931-32, the average number of imported bricks had fallen to 1,097,455, and the value to Rs. 2,85,903.

In addition to the Raniganj coalfield and Jubbulpore localities which have been mentioned already, fire-clays have been found at numerous other places and many of them have been proved by experiment to be of good quality. Amongst such localities are the following: Jawai, in the Khasi and Jaintia hills of Assam; Patarghatta hill, near Colgong, Bhagalpur district, Bihar and Orissa, interstratified with white pottery clays; many localities on the western side of the Rajmahal hills of the Santal Parganas in the same province, associated with thin coal seams; near Raipur, in Gwalior State and in the neighbourhood of Umaria in Rewah; near Golhalli, Bangalore district, Mysore, where they are exploited for the manufacture of fire-bricks by the City Tile & Brick Works of Bangalore; and in the vicinity of the Kolar goldfield.

# INDIA'S MINERAL WEALTH

## ANALYSES OF INDIAN FIRE-CLAYS

LOCALITY	SILICA	ALUMINA	FERRIC OXIDE	LIME	MAGNESIA	ALKALIS	TITANIA	LOSS
Gourangdi ...	50.48	35.06	0.64	0.33	0.20	1.13	...	12.12
Patlabari ...	53.58	30.88	0.68	0.28	0.22	1.40	...	12.98
Barakar ...	53.70	29.47	1.50	Trace	0.61	2.39	2.20	10.10
Churulia ...	47.88	37.13	0.79	0.48	0.18	0.54	...	12.94
Jubbulpore ...	62.92	25.29	1.08	0.57	0.29	0.58	...	9.35
Malur ...	68.50	19.55	1.22	0.69	...	...	...	9.50 <sup>1</sup>
Devangonthi	48.90	39.97	0.63	0.26	...	...	...	9.60 <sup>1</sup>

The first two analyses are by E. Spencer, quoted by E. R. Gee.

The next three are quoted by W. H. Bates.

The last two are supplied by the Kolar Brickmaking Co. Ltd.

The first four localities are on the Raniganj coalfield.

## SILICA BRICKS

Silica bricks are used in roofing steel furnaces where temperatures of 1,650° C. are reached and the conditions of rapid heating and cooling would quickly disintegrate ordinary fire-bricks. They also find an application in the construction of by-product coke ovens. There are two factories in India engaged in the manufacture of refractories from almost pure silica and both are on the Raniganj coalfield. The Kumardhubi Fire-Clay & Silica Works of Messrs Bird & Co., founded in 1915, includes ten beehive, coal-fired kilns of down-draught type, each with a capacity of 50,000 bricks. The Lal Koti Silica Works of Messrs. Burn & Co., which commenced in 1918, are at Raniganj, and have ten kilns, ranging from 20 to 26 feet in diameter and capable of producing about 1,000 tons per month. The raw material used in both cases is a quartzite either from the Gaya district or from the Kharakpur hills of Monghyr district. After crushing this rock to a suitable powder, a certain amount of lime is added as a bond for bricks of the normal type, or of clay for special coke-oven bricks, before the material is burnt. Both as regards tests to standard specifications and in the more certain one of actual use, Indian silica bricks have proved equal to those made in other countries, and practically no foreign material of this type has been imported for many years.

<sup>1</sup> Combined water and organic matter.

Bates estimates the annual capacity of the two works at 20,000 tons, though in 1932 the quantities actually sold did not exceed 8,000 tons. The industry at present depends on the Tata Iron & Steel Co. for its existence, and its future is bound up with the extension of the steel industry in India.

#### ANALYSES OF QUARTZITES USED FOR SILICA BRICKS<sup>1</sup>

LOCALITY	SILICA	ALUMINA	IRON	LIME	MAGNESIA	ALKALIS	LOSS
Gaya Dist. ...	97.15	0.76	0.91	0.10	0.01	0.08	0.20
Monghyr Dist.	96.86	1.26	0.14	0.38	0.14	0.13	...

#### THE TRADE IN CLAY AND CLAY PRODUCTS

In Table XX, the average annual values of the imports of clay and clay products are summarized over a period of thirty years commencing in 1903. The outstanding fact that they reveal is that in spite of the large quantities of earthenware, bricks, tiles and pottery of various descriptions made in the country, the excess of the demand over the internal production still costs India, approximately, one crore of rupees per annum in imported goods and indicates the wide scope which still exists for the development of her clay industries in general.

Besides being very incomplete, the official statistics of clay production in India, with the exception of china clay, do not differentiate between the varieties of clay quarried or the purposes to which they are put. As they throw little light on the true situation no attempt is made to classify them here.

#### MAGNESITE

Magnesite (magnesium carbonate) is a member of a group of minerals known as the rhombohedral carbonates, to which calcite (calcium carbonate), dolomite, calcium and magnesium carbonate and siderite (the carbonate of iron) also belong. The molecules of magnesite and siderite may combine and form a series of mixed carbonates intermediate in composition between magnesite and siderite, and the

<sup>1</sup> Quoted by W. H. Bates.

**TABLE XX**  
**AVERAGE ANNUAL VALUES OF CLAY AND CLAY PRODUCTS IMPORTED INTO INDIA**  
*In Rupees*

PERIOD	EARTHEN- WARE AND PORCELAIN	EARTHEN- WARE PIPING	BRICKS AND TILES	CLAY	AVERAGE TO- TAL ANNUAL IMPORTS	AVERAGE TO- TAL EXPORTS AND RE-EXPORTS	EXCESS OF CONSUMPTION OVER PRODUCTION
1903-04 to 1907-08 ...	34,42,920	1,29,720	8,01,615	89,835	44,64,090	4,59,090	40,05,000
1908-09 to 1913-14 ...	51,44,745	91,800	15,54,765	1,47,600	69,38,910	4,83,960	64,54,950
1914-15 to 1918-19 ...	47,01,060	1,37,985	20,89,065	1,49,910	70,78,020	4,85,910	65,92,110
1919-20 to 1923-24 ...	78,10,062	1,66,708	36,90,782	1,81,207	1,18,48,759	9,63,885	1,08,84,874
1924-25 to 1928-29 ...	76,06,875	1,51,958	26,12,155	80,355	1,04,51,343	7,80,318	96,71,025
1929-30 to 1932-33 ...	52,62,766	18,203	18,52,275	48,070 <sup>1</sup>	71,81,314	6,24,696 <sup>1</sup>	65,56,618

<sup>1</sup> Figures for 1932-33 not available.

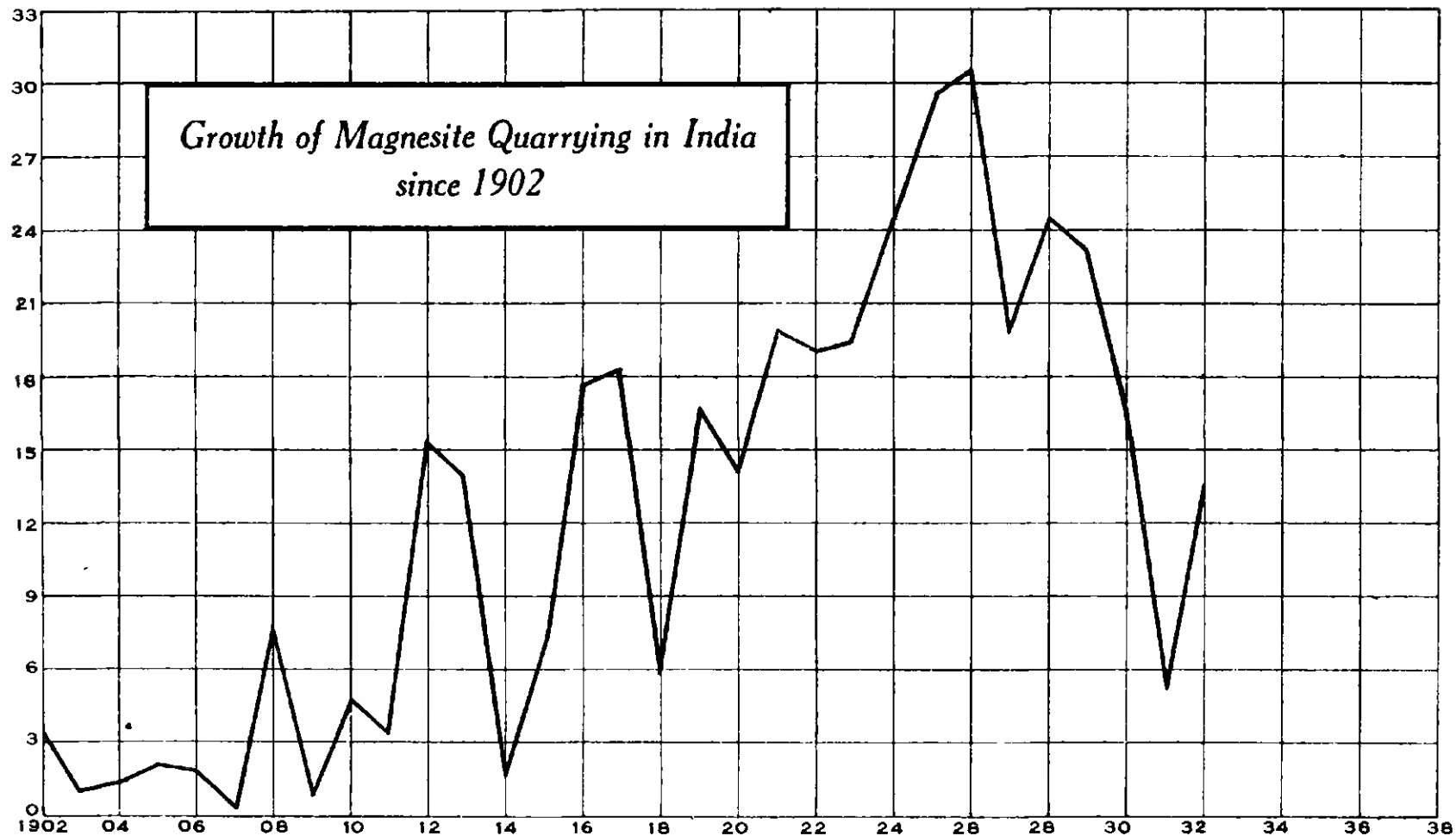
mineral breunnerite is one of these. It occurs near Dev Mori in the Idar State, Bombay and in the neighbouring State of Dungapur in Rajputana, but is of no economic importance at present, though it is worked in very large quantities in other parts of the world. The magnesite of Southern India belongs to the compact type and is a hard, white, brittle mineral which resembles unglazed porcelain and breaks with a conchoidal fracture. The granules of which it is composed are microscopically small so that its crystalline structure is not visible to the naked eye.

Dr Heyne is supposed to have discovered the great magnesite deposits of the Chalk hills, Salem district, Madras, in the first decade of the nineteenth century, and in 1825 they were specially brought to the notice of the Madras Government by Dr Macleod, who proposed to use the mineral in cement manufacture. The area was surveyed by W. King and R. B. Foote in 1864, and again by C. S. Middlemiss in 1896. A paper on the Indian magnesite industry by H. H. Dains appeared in 1909, and another by C. H. B. Burlton on 'Magnesian Cement in India' in 1912. The commercial development of the Salem deposits is due to the Magnesite Syndicate Ltd., founded by H. G. Turner about 1900. Production commenced in 1902, and from that time until the end of 1933, the Indian output was 402,295 tons, of the purely nominal value of £273,709, and for this total the Salem deposits were alone responsible for over 93 per cent, the remainder coming from Mysore, where quarrying by the Tata Iron & Steel Co. Ltd. commenced in 1913. The highest recorded production from the Salem district was in 1925, when the output reached 29,620 tons. For the five years ending 1930, the annual figures averaged 21,176 tons. Since then the tonnages have been considerably lower owing to the world depression, particularly in the iron and steel industry. The total Indian production for 1934 was 14,975 tons of magnesite.

The plains surrounding the Chalk hills are composed of ancient crystalline rocks, and Middlemiss showed that the hills themselves are essentially two great intrusive masses of ultra-basic rocks which have become serpentized. The magnesite occurs over an area of about  $4\frac{1}{2}$  square miles in an intricate network of veins piercing them. The reserves of the mineral in the hills are practically unlimited and their richest portions stand up in hillocks rising some 140 feet above the plains. Nodules and thin veins of chromite occasionally occur with



THOUSAND  
TONS



Graph 15

the mineral and the general appearance of the whole occurrence can be clearly seen in the accompanying photograph kindly supplied by the Magnesite Syndicate Ltd (see Plate VI). Petrological research by Sir Thomas Holland proved that the magnesite originated not from the conversion of serpentine derived by the ordinary process of hydration from the olivine, which is the commonest mineral in the ultra-basic rock (dunite), but independently through the action of carbonic acid upon the olivine, under conditions of high temperature and pressure. This conclusion means that the formation of the magnesite is not a superficial phenomenon, but that it may be anticipated to extend to considerable depths.

The mineral occurs at Dod Kanya and Dod Katur in the Mysore and Hassan districts of Mysore State, forming vein deposits in serpentine of the usual type. At the first named locality a serpentine lens about three-quarters of a mile long and a quarter-of-a-mile wide, intrusive into schists, is traversed by veins of magnesite, and the reserves are believed to amount to some hundreds of thousands of tons.

The only other Indian occurrence which need be mentioned here is that to the north of Bania Pani, seven miles south of Wad, Jhalawan, eastern Baluchistan, where E. W. Vredenburg found magnesite veins traversing serpentine intrusions, regarding which he wrote as follows: 'Magnesite thus situated and in such abundance might be worth extracting in the event of a railway extension to Las Bela.'

Magnesite is the source of magnesia, the oxide of magnesium, and there are two commercial varieties of this substance. When the mineral is burnt in a kiln at a temperature not exceeding 1,000° C., a product is obtained which still contains two or three per cent of carbon dioxide. This is known as 'caustic' magnesia. It 'slacks' when exposed to the air and, in conjunction with magnesium chloride, is the chief component of the 'oxy-chloride' or 'Sorel' cements of the patent flooring and other trades, in which it is used for the construction of fire-proof partitions, artificial stone, tiles, abrasive wheels, etc. When the calcining operation is carried out at higher temperatures

such as lead and copper smelting. The greater proportion of the magnesite produced is used in this 'dead-burnt' form.

Magnesite also finds a limited application in the manufacture of certain varieties of vitreous porcelain, in the preparation of medicinal compounds, in fire-resisting paints and as a constituent of non-conducting materials for steam-pipe and boiler laggings.

Part of the Salem product is shipped from Madras in the raw state, but considerable quantities of both 'caustic' and 'dead-burnt' magnesia are also made on the spot. The average annual quantity of both varieties so produced increased from 6,153 tons for the five years ending 1923, to 10,659 tons, the average for the five years ending 1928. Magnesite is used for the preparation of refractories in India by the Kumardhubi Fire-Clay & Silica Works, in the Lal Koti Silica Works of Messrs Burn & Co. Ltd., Raniganj and by the Tata Iron & Steel Co. Ltd. The furnaces used in the manufacture of Indian steel by the basic process are lined with magnesia bricks, while the bottoms are further concreted with a mixture of dolomite and granulated magnesia known as 'peas'. The monthly amount used at present by the Tata Iron & Steel Co. Ltd., according to W. H. Bates, is about 75 tons of bricks and 100 tons of 'peas'. Compared with the Austrian magnesia brick formerly used, but which it has now displaced, the Indian brick is said to give equal results and to possess some qualities which make it more durable.

Of the total magnesite exports for the three years 1929-30 to 1931-32, which amounted to 17,779 tons, valued at Rs. 18,39,135, 40.5 per cent went to the Netherlands, 36 per cent to the United States of America, 10 per cent to Germany, 9 per cent to the United Kingdom, 2 per cent to Belgium and the remainder to other destinations. In normal times the United States is the largest consumer and additional quantities are taken by Belgium.

There is no reason to doubt that with the advent of more prosperous times in the world generally and with the growth of the iron and steel industry in India itself, the magnesite business will continue to expand.

all change into mullite, which has the chemical composition  $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ . Kyanite is transformed at the lowest temperature but expands considerably in the process; sillimanite at the highest with very little alteration of volume; but both are calcined at high temperatures before use as refractory materials which are now finding increasing applications in many parts of the world. The properties of bricks made from these minerals have been summarized as follows: high softening point of over  $1,800^\circ\text{C}$ ., and perfect stability to that temperature; very low coefficient of expansion and freedom from volume changes; neutral reaction and great resistance to the corrosive action of many slags and the abrasion of moving charges; equal efficiency in either oxidizing or reducing atmospheres; great mechanical strength at high temperatures; high electrical resistance and moderately high thermal conductivity. These characteristics render the calcined material eminently suitable for the manufacture of many refractory articles such as bricks, blocks, shapes for industrial furnaces of all kinds, glass furnaces, pottery kilns, electric steel melting furnaces, rotary and tunnel kilns; pots, retorts, muffles, crucibles and saggars; electrical refractories, electrical hot plates and fires, gas fires, fire bars, tubes and the like. In the construction of fire boxes and combustion chambers of all kinds and especially of glass furnaces, tanks and pots, this material has shown marked economic advantages. It is not, however, suitable for general metallurgical work.

The development of the Indian industry is largely due to the efforts of Mr H. Brelick and the P. B. Sillimanite Co. Ltd., and although introduced only ten years ago into England there are now in various parts of the world, including the United Kingdom, the United States, most of the continental countries of Europe and Australia, hundreds of refractory manufacturers using Indian material prepared and supplied by this firm.

The discovery of the Assamese sillimanite deposits, mentioned later under CORUNDUM, was an accidental one due to the inclusion of the mineral in a consignment of corundum, which failed to satisfy its proper tests in the United Kingdom in 1921. The production of kyanite commenced in 1924, and the total tonnage recorded from that time until the end of 1933 was 32,972 tons, valued at Rs. 4,21,299, which was all exported to various European countries and to the United States of America. For the five years ending 1933, production averaged 5,107 tons per annum and is likely to become increasingly important.

With the exception of insignificant parcels from Ajmer-Merwara, Rajputana, and from Mysore, the whole output comes from Singhbhum, Bihar and Orissa, and over 96 per cent of it from Lapsa hill in Kharsawan, where it is quarried by the Indian Copper Corporation Ltd. J. A. Dunn has shown that in Singhbhum, kyanite rock, associated with quartz-kyanite rock, occurs at intervals along a belt of country nearly 70 miles in length, the deposits striking parallel with the 'copper belt', from Lapsa Buru through the States of Kharsawan and Seraikela, thence turning south-east through Dhalbhum and finishing close to the border of Mayurbhanj. The prevalent rock of this belt is an aluminous muscovite schist, though hornblende schist is also frequent. At Lapsa Buru there are enormous beds of kyanite-quartz rock containing segregations of massive kyanite. It is often of the radiating, columnar variety, and crystal blades of over twelve inches in length have been seen. The debris at the surface and to a depth of only one yard is estimated on a very conservative basis to contain 214,000 tons of kyanite, and the total may be ten times this amount.

Smaller quantities have been obtained from Ghagidih, close to the Seraikela border, and about two miles south of Jamshedpur. Here the rock association is much the same—kyanite-quartz rock and massive rock kyanite occurring with mica schists and rarer hornblende schists. The mineral is collected from the surface deposits and 20,000 tons are believed to exist down to a depth of one yard. There are other deposits near the Rakha mines, at Badia-Bakra and Kanyaluka. Kyanite-quartz rocks, apparently similar to those of Singhbhum, occur, according to Swaminathan, on the eastern flank of Devarakonda and other localities in the Nellore district, Madras.

In discussing the origin of these and other deposits of related minerals in Northern India, Dunn concludes that their sedimentary origin and their derivation by the metamorphosis of bauxitic or other aluminous clays are indicated. The extraordinary persistence and regularity of the Singhbhum belt suggests to him a zone in the Archæans containing lenticles of aluminous rock, and he states further that the Indian deposits appear to be unique.

Kyanite as a gem stone is considered elsewhere.

The sillimanite-corundum deposits of the Khasi plateau in Assam, investigated first by the late F. W. Walker, and of which thirteen are known, lie in an area three miles long and one mile wide near Sona

Pahar, Nongstoin State. In the immediate neighbourhood, J. A. Dunn found the local rocks to be granite-gneiss and biotite-sillimanite-cordierite-quartz rock, interbedded with the latter being a sillimanite-quartz schist. Both are older than the granite-gneiss which intrudes them in places. Most of the deposits are massive sillimanite with a little corundum, one or two almost entirely of corundum, and several contain sillimanite alone. Impurities are not abundant and are mainly rutile, a little biotite and iron ore. Dunn estimates that down to a depth of ten feet there is a minimum of 83,000 tons of the mineral available, and the actual quantity may be very much more than this.

The corundum-sillimanite deposit of Pipra, Rewah State, Central India, is referred to in connexion with the first-named mineral, and it need only be mentioned here that Dunn, taking an average depth of only thirty feet into consideration, has calculated that about 100,000 tons of good material are available, though the possibility of exploiting the better grade is limited, owing to its intimate mixture with impure material.

Other unimportant deposits of corundum and sillimanite occur in the Bhandara district of the Central Provinces, while specimens of the latter mineral have been obtained from southern Hsipaw, one of the Federated Shan States.

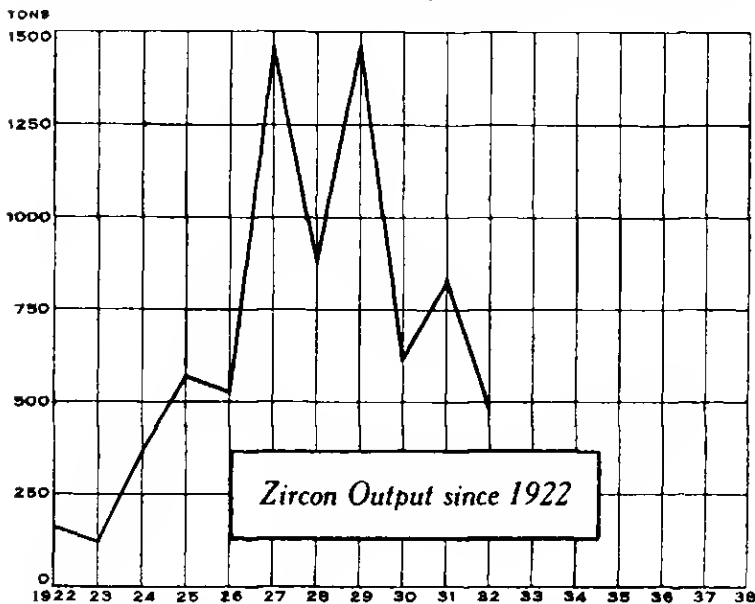
## ZIRCON

Zircon, the orthosilicate of zirconium, is one of the commonest accessory minerals in all types of igneous rocks, but is especially prevalent in the more siliceous kinds such as the granites, syenites, diorites, etc., and the younger eruptives. It is very characteristic of the nepheline syenites. The sands derived from such rocks usually contain granules of the mineral which, owing to their higher specific gravity, remain in the concentrate when the lighter portions are washed away. Larger crystals are sometimes found in the pegmatitic varieties of the nepheline syenites and other rocks, and when cut by the lapidary yield the brilliantly lustrous gems known as the hyacinth and jargoon, which are described under GEMS.

Large quantities of fine, granular zircon are obtained in the treatment of the beach sands of the Travancore coast by the Travancore Minerals Co. Ltd. The sands, which are also the source of monazite, ilmenite and rutile, contain about six per cent of zircon,

which is recovered by gravity concentrators and magnetic separators at the company's works at Manavalakurichi.

The mineral is used in the preparation of ferro-zirconium and other alloys for which there is a small demand in the steel industry, and of the oxide zirconia, used to some extent as an opacifier in the manufacture of white and grey enamels for iron ware. The principal application of zirconia however, is as a high grade refractory material. For this purpose, after calcination, it is ground to a paste with a suitable



Graph 16

bonding material, moulded into the shapes required, and burnt at a very high temperature. Bricks made in this manner are stated to be basic in character, highly refractory, with a low heat conductivity and a very small coefficient of expansion. The material is also used in the manufacture of crucibles and high temperature cements. Zirconia products are employed in the steel and other metallurgical industries, and generally in situations where a highly refractory material resistant to sudden variations of temperature and to chemical corrosion from molten slags and gases, is required.

Zircon production commenced in 1922, and from that time

until the end of 1933, 8,160 tons, valued at £55,739, had been won from the Travancore deposits. The average annual production for the three years ending 1933 was in the neighbourhood of 650 tons. Large reserves are known to exist and it is expected that the industry will expand in the future as the advantages of zirconia refractories become better appreciated.

### GRAPHITE

Graphite, plumbago or black-lead, the soft modification of the natural forms of carbon, is the principal mineral product of Ceylon, where it has been mined for over a century. The Archæan rocks of the island are southward extensions of the strata which underlie the greater part of Southern India, and the graphite occurs in many places, disseminated through limestones and gneisses, in seams which follow the foliation of the rocks and in true fissure veins which cut across their bedding. The mineral was discovered in Travancore, where it occurs in similar rocks under much the same conditions, in 1840, and in the early years of the present century was mined by the Morgan Crucible Co. Ltd. Between 1901, when regular returns first became available, and 1911 when operations ceased, 35,000 tons were produced. Many localities are known and include Arumanallur, with a narrow, branching vein in decomposed pegmatite; Avannesswaram, with a vein in garnetiferous gneiss, and Kinpallikonum where the mineral is in a felspar vein traversing garnetiferous gneiss. Both in Travancore and the adjoining district of Tinnevely, graphite has been found in the surface lateritic deposits formed from the crystalline rocks below. The most productive mine in Travancore was at Velland in the Nedamangad taluk. The geological circumstances of the Travancore occurrences are held by some authorities to prove that graphite can sometimes originate under conditions which preclude the supposition of an organic origin for the mineral.

Small parcels of graphite came from the Godavari district in the years 1904, 1905 and 1908 and from the Vizagapatam district in 1906, 1910 and 1911, but the total quantity from both was only 452 tons, and by 1912 graphite mining was extinct in India. The Great War stopped the import trade and led to the opening-up of deposits in the Kalahandhi State of Orissa, which yielded 510 tons between 1915 and 1919, and in Ajmer-Merwara, Rajputana, whence 1,169



tons were obtained in the same period. The total Indian production since then (1919) has been a further 56 tons from Ajmer-Merwara (1920 and 1929), 82 tons from the Patna State (1919 and 1920), 47 tons from the Betul district, Central Provinces (1920 and 1921), 20 tons from Mysore (1922), 1 ton from Bhagalpur district, Bihar (1921) and  $11\frac{1}{2}$  tons from the Kistna district, Madras (1931 and 1932).

The graphite deposits of Kalahandi, Patna and other States of Orissa which have been known for seventy years, and probably those of the Vizagapatam, Godavari and Kistna districts of Madras as well, are associated with rocks of the Khondalite series. These are parapschists and include garnetiferous quartz-sillimanite rocks, garnetiferous quartzites, calciphyres and graphitic schists, overlying the charnockites and the granitoid gneiss. At Koladi Ghat in Kalahandi, according to Sir Lewis Fermor, bands of graphite 12 to 20 inches thick occur in clay resulting from the decomposition of khondalite. At Densurgi, in the same State, impure graphite bands are found in a decomposed gneiss. The Daramgarh and Domaipalli deposits of Patna State are in graphite schists, associated with garnetiferous gneissose schists. The inaccessibility of the areas prevents their exploitation in normal times, but during the war they yielded two grades of foundry graphite.

The mineral occurs at several places in Rajputana, particularly in bands of graphitic limestone, graphitic schist and carbonaceous mica schists near the base of the Delhi system, but is usually of poor quality.

The Sohna deposit, Gurgaon district, Punjab, has been known since 1861 and consists, according to A. M. Heron, of two layers rich in graphite, six inches and three to four feet thick respectively, in Alwar schists but the quantity is too small and the quality too poor to make it of any value.

The mineral also occurs in schists near Almora, United Provinces and in a vein between Tsuntang and Lachen in Sikkim, while from Kashmir, C. S. Middlemiss has described a large, low grade deposit of the amorphous variety of doubtful utility, near Braripura, Urie tehsil.

Graphite is often freely distributed through the crystalline limestones of the Mogok Stone Tract, Katha district, Burma, and unsuccessful attempts have been made to work richer lenticles near Wabudaung, Kyaukkyi, Onzon and elsewhere in the Thabeikkyin subdivision.

Graphite is used as a refractory material, as an ingredient in the manufacture of stove grate polishes and paints, for facing the surfaces of moulds in foundry work, as a lubricating agent for certain types of machinery, in electrical work for commutator brushes, and in making 'lead' pencils. Although graphite crucibles and refractories have been made on a small scale in India, manufacturers have hitherto failed to obtain regular and unadulterated supplies of the mineral, and until these are forthcoming, importation of foreign material is likely to continue.

In the Indian Customs Returns graphite appears under the heading 'Paints and Colours' and again separately as 'Graphite Crucibles'. For the five years ending 1933 the imports under the former averaged 621 tons, valued at Rs. 1,54,162, and under the latter 170, valued at Rs. 1,69,451, annually.

### GLASS SANDS

Ordinary transparent glass is made by fusing together mixtures of sand, sodium carbonate and limestone. The proportions of the ingredients used in the 'batch', or mixture, vary greatly, but a typical one consists of about 300 parts of pure sand, about 100 parts of sodium carbonate (soda ash) and some 50 parts of pure limestone. Crystal and flint glasses contain lead oxide instead of lime, whilst Bohemian glass contains potash in place of soda. Coloured glasses are made by introducing various metallic oxides into the mixture.

An inferior glass has long been made in India by fusing the alkaline efflorescence known as *reh*, which in its impure state in certain localities contains sufficient silica and lime for the purpose, though sand is sometimes added either in that form or as powdered quartz. In 1856, according to G. Smith, there were two glass factories near the Lonar soda lake of the Buldhana district, Central Provinces, engaged in the manufacture of bangles. Again, an indigenous industry has existed for over 120 years at Matrod in the Chitaldroog district of Mysore, using local quartz, and soda from surface efflorescences in the same district. Other examples might be quoted from the Punjab.

The chief difficulty in manufacturing glass in India until comparatively recent times was the absence of knowledge regarding sands of the requisite degree of chemical purity and mechanical fineness. Glass sands must be free from impurities such as iron compounds,

which impart undesirable colours to the finished article, and they should also be of proper grain, in order that the chemical reactions which take place in the crucible or furnace may proceed evenly and quickly during fusion and leave no undissolved particles. On the other hand, too fine a grain has certain disadvantages and may give rise to a turbid glass. The famous and oft-quoted Fontainebleau sand contains 99.7 per cent of silica, 0.19 per cent of alumina, 0.002 per cent of iron oxide and 0.14 per cent of lime, while 85 per cent of it consists of particles between one quarter and half a millimetre in diameter. Many of the better known British, continental and American glass sands contain over 99.5 per cent of silica and may be used in the preparation of the finest wares, but for commoner grades such as bottle and window glass, such a high silica percentage is not necessary. Sands containing up to 0.02 per cent of ferric oxide may be utilized for making window glass, without the use of the corrective manganese oxide as a decolourizing agent. Although alumina may be useful in glasses made for special purposes, it is usually harmful when present in excess in the original sand, which should also be free from magnesia and organic matter.

In recent years good glass sands have been found in many parts of India. The bedded Damuda sandstones of Mangal Hat and Pir Pahar in the Rajmahal hills, Bihar and Orissa, were investigated by Murray Stuart in 1908. After crushing and washing they yield a sand from which ordinary glass can be made, though their kaolin content renders them unsuitable for high grade material. Beds of sand practically free from iron compounds occur also at Patarghatta in the Bhagalpur district of the same province. A crushed and graded sandstone of Vindhyan age from Loghra and Borgarh (Naini), in the United Provinces, yields a remarkably pure sand, which is in actual use at a number of Indian glass works, while others employ sands from Jaijon Doaba, Hoshiarpur district, Punjab, and from Sawai Madhopur, in Jaipur State, Rajputana. Good sands are also obtainable from Tertiary sandstones at Sankheda and from the Sabarmati river at Pedhamli, both in Baroda State; from the friable sandstones of Madh in Bikaner; from a loosely compacted grit, near Barodhia in Bundi State, Rajputana; and from an old sea beach at Ennore, north of Madras. According to D. N. Wadia, a soft, white quartzite of exceptional purity, suitable for easy conversion into a

glass sand exists south-west of Batala hill in the Gagrian defile, Punch State, Kashmir. The percentages of silica in typical sands from Patarghatta, Naini, Sankheda and Pedhamli are 96.00, 98.95, 99.39 and 98.10 per cent and the amounts of ferric oxide traces, 0.02, 0.04 and 0.04 per cent, respectively. 'Within recent years,' writes C. S. Fox, 'special types of apparatus have been designed and used in crushing, grinding, washing, grading and drying sands for glass-making purposes. It is certain that by using some of these machines in India many local deposits of sand and sand rock will be made available for use as good quality material. The price will, of course, be increased, but the market prices should still be less than those paid for similar sands in Europe, where prices f.o.r. at glass works range from 12 shillings to 40 shillings a ton in the case of the natural sands, and up to 120 shillings or more for picked, crushed and graded quartz rock.'

Glass works, using local sands or sandstones, have been established in many parts of India, amongst which may be mentioned Allahabad and Firozabad in the United Provinces, Ambala in the Punjab, Talegaon in Berar, Jubbulpore in the Central Provinces, and various localities in Bombay and in Madras. During the war the glass industry received a great impetus owing to the difficulty of obtaining imported supplies, and by 1921, no less than thirty-two firms were engaged in the manufacture in India, as compared with three reported to be in operation during the pre-war quinquennium. In the first edition of this book, published in 1923, it was remarked that owing to the unsuitable locations of some of these concerns, to which raw material and fuel had often to be transported hundreds of miles by rail, it was difficult to see how they could all be carried on profitably in normal times. By 1924 the number had dropped to 17 and by 1928 to 16. Indian glass works have, as the following table proves, made no impression on the enormous quantities of glass which are imported into the country.

TABLE XXI

## INDIA'S GLASS IMPORTS

PERIOD		AVERAGE ANNUAL VALUE	
		Rs.	£
1898-99	...	...	441,529
1903-04	...	...	661,377
1907	...	...	Over 900,000
1908	...	...	800,000
1913	...	...	1,300,000
1909-13	...	1,58,66,820	1,057,788
1914-18	...	1,30,80,795	872,053
1919-23	...	2,46,92,330	1,935,679
1924-28	...	2,56,03,950	1,899,546
1932-33	...	1,86,88,962	...

An analysis of the detailed import returns for the period 1924-28 shows that about half of the foreign glass which reaches India is in the form of the bangles and beads with which the feminine portion of the population adorns itself, glass bangles accounting for 35.5 per cent of the total imports, and beads and imitation pearls for a further 12.9 per cent—a grand total of 48.4 per cent. Bottles are the next most important item with 13.9 per cent, and are followed by sheet and plate glass with 12 per cent of the total. Globes, glass parts of lamps and funnels account for 7.1 per cent, table-ware, including decanters, etc., for 3.9 per cent, scientific glassware for 0.8 per cent, unspecified descriptions for 12.2 per cent and Government stores for the remaining 1.7 per cent.

The Great War enabled Japan to capture much of the Indian trade in glassware, particularly in bangles and beads, and in 1919 she supplied 65 per cent by value of the total imports: a further 20 per cent came from the United Kingdom, whilst Belgium, Austria-Hungary and Italy sold between 1 and 2 per cent each. Japan's position was soon lost, and the figures for the period 1924-28 show that the trade of Austria-Hungary of pre-war days now goes to Austria and Czecho-Slovakia, which supplied between 27 and 28 per cent by value. A corresponding amount has been lost by Japan, whose share has fallen to 26½ per cent. The United Kingdom had 10 per cent of the value, a quantity equal to that of Belgium. Italy supplied just under 3 per cent, and Germany had reappeared with 17 per cent by value of the returns.

## CHAPTER IX

### MINERAL COLOURS AND ABRASIVES: OCHRES, BARYTES, ILMENITE, CORUNDUM AND GARNET

THE mineral colours may be divided into three groups as follows: (1) Natural mineral pigments, (2) pigments made from ores or ore residues, and (3) chemically manufactured inorganic pigments. The first group includes the ochres, oxides, umbers, siennas, ground slate and shale. In the second are substances such as the red oxides made from roasted pyrites; while the last contains a very large number of colours including white lead, chrome yellow, and Prussian blue. Many mineral substances are consumed in the paint industry and among them may be mentioned asbestos, barytes, kaolin and clays of various kinds, graphite, gypsum, magnesite, mica, silica, and soapstone, but here we are concerned only with the members of the first group of the classification.

#### OCHRES

The yellow ochres all contain hydrated ferric oxide as their colouring principle, mixed with varying quantities of sandy or clayey materials. The natural soft red earths, both ochres and oxides, owe their value to the presence of ferric oxide, and it is interesting to recall that the original 'Indian red' of commerce was a bright red oxide with a purplish tinge which came from Ormuz island in the Persian gulf.

The abundant occurrences of iron ores and laterites in India lead to the presence of ochres in very numerous localities and it would be impossible within reasonable limits, even if full information were available, to enumerate all the places where the inhabitants obtain those natural pigments, generically called *geru*, which are used in the decoration of homes and temples and for many other purposes as well. The annual production of ochres in India, so far as it appears in the official statistics—which relate rather to large amounts won for industrial purposes than the small collections from innumerable

localities for domestic uses—averages about 8,000 tons per annum and most of this comes from Central India, though the Central Provinces has increased its output greatly within recent years. The total recorded production from 1906 onwards to the end of 1934 was approximately 117,500 tons. Of the 109,500 tons raised to the end of 1933, 55 per cent was supplied by Central India, 24 per cent by the Central Provinces, approximately 9 per cent by Gwalior and the remainder by Rajputana, Madras, Bihar and Orissa, the United Provinces and Mysore, in the order named. Ochre production was greatly stimulated in the industrial boom which followed the war, the total output for the quinquennium 1919–23 being over 30,000 tons, as compared with less than half this amount for the previous one. The next quinquennium witnessed a decline to about 23,000 tons, but from 1929 to 1933 the total reached 39,361 tons.

The Central Indian ochres come mainly from the States of Panna and Sohawal. In the former they occur in association with ferruginous laterite and are worked by Olpherts Paint & Products Ltd., Turner, Morrison & Co. Ltd., and Abdul Sattar & Co. The Central Provinces material is derived chiefly from the Jubbulpore district, where the Jauli mines appear to have been operated extensively in times past and were taken over by Mr Olpherts about 1870. This ochre has been described as 'a rich, micaceous iron with hæmatite' and is found in rocks of Dharwar age. In Gwalior, the ochre mines of Behat in the Gird district were leased in 1928 by Dhari Ram and the Rajputana Minerals Co. Ltd. There are many references in literature to the ochres of the Madras Presidency, but only two can be quoted here. 'Along the western base of the Ramandrug section of the Sandur hill group (Bellary district)', wrote R. Bruce Foote, 'a vast quantity of intensely red, earthy hæmatite lies scattered thickly over the great talus. This also seems to be a very pure mineral and would yield a splendid pigment for the mere trouble of collecting and grinding it.' Semi-ochreous masses found on weathered schists and traps of Dharwar age in the same region are used to some extent as colour washes for house painting, the commoner colours being dull orange and drab, but purplish-grey and lilac are met with, and red tints ranging from pale pink to deep red. H. F. Blanford drew attention to a bed of impure yellow ochre in the Cuddalore sandstones at Trivandipuram in the Trichinopoly district, which when ground and levigated yielded a very good pigment; while a clay at

Terany, treated in the same way, gave a deep red variety. Ochres have been won on a small scale from Janehar, Tumkur district, Mysore and used in the Mysore Royal Paint Works of Bangalore for brown and chocolate pigments, a graphitic variety in particular being employed to make a grey paint. P. N. Bose states that the red ochres of Padvania, Valia taluk, Rajpipla State, Bombay, have been worked for many years and that, about 1907, some 120 tons were being removed annually.

Among the producing districts of Bihar and Orissa are Puri and Singhbhum. Sir Lewis Fermor has stated that the ochres of the former may be derived either from laterite or decomposed khondalite, while those of the latter may come from laterite, altered Dharwarian phyllites or from iron ore deposits of the same age. Amongst the Singhbhum localities for yellow ochre are Goilkhera, Kocha and Jerakel. J. A. Dunn has recently discovered homogeneous purple clay which should make an excellent ochre, to the south-west of Kubasa, Ranchi district. As regards Rajputana, A. M. Heron (1935) refers to the red, yellow and purple ochres which are commonly associated with the iron ore deposits and ferruginous breccias in the Alwar series, and with the masses of breccias in the Aravalli limestones. These natural pigments are in considerable local demand for decorating houses and pottery. A large and easily accessible deposit is that half a mile north of Barara, or two and a half miles west of Chitorgarh Junction in Udaipur State.

Yellow and purple ochres are also associated with the hæmatite and limonite ores occurring at the junction of the Jhiri shales and the Upper Rewah sandstone in the Vindhyan rocks of Bundi State. D. N. Wadia reports pockets of fine, yellow, brown and umber ochres, the residue of nests of pyrite, enclosed in the Salkala slates and associated with the graphite of Reshian in the Urie tehsil of Kashmir. To the east and south-east of these deposits are the ochre beds described by C. S. Middlemiss, where upwards of 200,000 tons of ochres of good quality, ranging from pale yellow, through Indian yellow and Venetian red, to deep browns, are believed to be available. Finally, a yellow ochre deposit at Panpe in the Myingyan district of Burma has a maximum thickness of 30 feet.

At one time India supplied large quantities of excellent yellow ochres to the United Kingdom, but the trade appears to have ceased. The crude, unwashed materials which are sometimes sent as samples cannot bear the costs of transport, or compete successfully with



higher grades from nearer sources. The attention of the prospector should be devoted to the discovery and preparation in suitable areas of colours possessing strong staining power, brightness of tint, fineness of texture and freedom from grit, as these are the chief factors which determine price. The possibility of occurrences of earths of the umber and sienna groups in India deserves more consideration than it has received in the past. The better grades of these materials are comparatively valuable products. They should be sought for in association with manganese ores of the lateritoid type.

N. Brodie has shown that the value of the paint and varnish materials used in India itself now amounts to some two crores of rupees annually, of which the greater part is spent on imported materials. Yet Indian resources of raw materials are not inferior to those of many regions in which paint and varnish are made on a large scale, indeed they are greatly superior to the majority of those of such countries. Brodie concludes therefore that India should export and not import such manufactures, a conclusion with which students of the subject must agree.

### BARYTES

Barytes, the sulphate of barium, is a heavy white mineral which finds its chief application in the paint industry and especially in the manufacture of lithophone.

The largest deposits occur in Madras. From one of these, Betamcherla, in the Kurnool district, extraction commenced in 1918, and by the end of 1931 over 24,500 tons had been removed from the district. In 1931 it was announced that barytes veins had been discovered in Pulivendla taluk of the Cuddapah district, the principal locality being Kottapalle, and in the Anantapur district. Systematic investigation of the region by A. L. Coulson in 1932 led to the listing of 60 localities of which only five had been previously recorded. Thirteen of these places are in the Cuddapah district, with 8 in the Pulivendla taluk, eleven are in the Anantapur district, with 8 in the Tadpatri taluk; and the remaining 36 are in the Kurnool district, with 29 in the Dhone taluk. Most of the barytes occurs either in replacement or fissure veins in the Vaimpalli limestones, or in the intrusive dolerite and basalt sills associated with them. The Vaimpalli limestones and slates form the upper part of the Papaghni series of the Cuddapah system, and in them are also found the chrysotile asbestos deposits of

Brahmanapalle (also in the Pulivendla taluk, described later). At Kottapalle there are over 30,000 tons of barytes in the first 20 feet of depth. The Mutssukota deposit may contain 75,000 tons. Four veins have been found near Nerijamupalle in Anantapur, the largest of which is from 3 to 11 feet wide and has been traced for more than half a mile along its strike.

A. L. Coulson who has recently (1933) published a memoir describing the barytes deposits of the ceded districts of Madras, considers that the barium solutions were derived from the magma responsible for the trap sills in the local Cuddapah rocks and that barytes was precipitated from them by solutions containing sulphuric acid. The latter were either another derivative of the same magma, or, as seems more likely in the majority of cases, were themselves produced by the leaching of sulphur compounds originally present in the Vainpalli limestones.

Barytes has been mined in the Alwar State of Rajputana since 1921, the total output up to the end of 1932 being 14,302 tons with a maximum production of 2,948 tons in 1929, which fell, however, to 161 tons in 1931 and 483 tons in 1932. According to S. K. Roy, there are four separate deposits, the most important being situated four miles north by east of Parisal, where a vein of pure white mineral about 15 feet thick has been traced for 110 feet. All the deposits are in the Alwar quartzites of the Delhi system. Accounts of these and other later discovered occurrences were given by K. L. Bhola in 1935.

Many other occurrences are described in the literature, and with one exception they all seem to indicate that it is a mineral of aqueous origin. It is found as concretions in the Belemnite shales of the Kalat and Las Bela States of Baluchistan; is frequently formed by the replacement of other rocks, as at Kolpotka, in Singhbhum; accompanies the ores of copper as a vein filling, as at Sleemanabad in the Central Provinces; or the ores of lead as in certain cases in Mawson, Federated Shan States; or, again, the ores of both copper and lead as in those near Mitau, Amherst district, Burma; and, finally, it sometimes occurs in veins alone, as at the Burma Corporation's Bawdwin mine, or in association with quartz or calcite. The network of veins composed entirely of quartz and barytes, which traverses porphyritic gneiss near Alangayam in the Salem district of Madras, is regarded by Sir Thomas Holland as an original magmatic segregation, a view which is not accepted by some authorities.

A table is given below showing the total recorded production, the imports and consumption of barytes in India up to 1932, for there are no exports of the mineral. Since that date, 9,464 tons were won up to the end of 1934. Consumption is expanding, and from an initial figure of 2,764 tons in 1918, it reached a maximum of 12,581 tons, worth Rs. 3,47,762, in 1930, falling since then owing to the general depression. The world's production of barytes is probably in the neighbourhood of half a million tons per annum, and most of this is used in the manufacture of lithophone, a white pigment containing zinc sulphide, zinc oxide and barium sulphate, which is made on an enormous scale in some countries. Indian imports of lithophone averaged 621 tons, valued at Rs. 1,54,162, for the three years ending 1932-33. Powdered barytes is itself largely used in the paint industry and as a filler for paper, rubber, oil-cloth, linoleum and similar products, but its chief outlet in the Indian Empire is for weighting the mud fluids which are circulated in oil wells while they are being drilled by the rotary system. It has also been employed as a furnace lining at the smelters of the Burma Corporation. According to N. Brodie, the use of barytes in paint manufacture is due to its cheapness, friability, inertness, transparency and low absorption of oil. It increases the stability of white paint and forms the basic material for many coloured ones. Its legitimate office as an inert pigment in the manufacture of colours has been described as the diffusion of the shade by its presence and the brightening of the tints which are prepared from it as a base.

Barium salts are usually prepared from the natural carbonate, witherite, in preference to barytes, and find applications in the manufacture of oxygen and hydrogen-peroxide, as chemical reagents, in the preparation of rat poisons and boiler compounds, as glazes for ironware and pottery, in glass-making, as water softeners, in luminous paint and in pyrotechny for the production of green flares.

The imports of barytes into India for the three years ending 1931-32 averaged 4,409 tons, valued at Rs. 2,44,374, shipped mainly from Germany to ports in Burma and Sind, whence they doubtless reached the Punjab and Upper Burma oilfields. To be acceptable to the petroleum industry it is essential for the mineral to be very finely powdered and it should pass through a 300-mesh sieve. The presence of silica is undesirable. The specific gravity must exceed 4.15 and the powder must contain 96 to 97 per cent of barium sulphate. Apart from

this outlet the possibilities of the future expansion of barytes mining in India depend on the future development of the paint and colour industry. According to Brodie, the value of the paint, varnish and paint-making materials used in India now amounts to some two crores of rupees annually, the greater part of which is spent on imported materials. The average annual value of imported paints and painters' materials for the five years ending 1932-33 was Rs. 1,16,50,997. In this case, too, the market value depends on the percentage of barium sulphate present, on the purity of the colour and the fineness of the powder. To be acceptable to the paint manufacturer, very close control of the milling operations for the production of the powder is essential to ensure uniformity in size of the various grades, and it is also necessary that the raw material should be free from iron compounds and other injurious substances.

TABLE XXII

## BARYTES: PRODUCTION, IMPORTS, CONSUMPTION

*Long Tons*

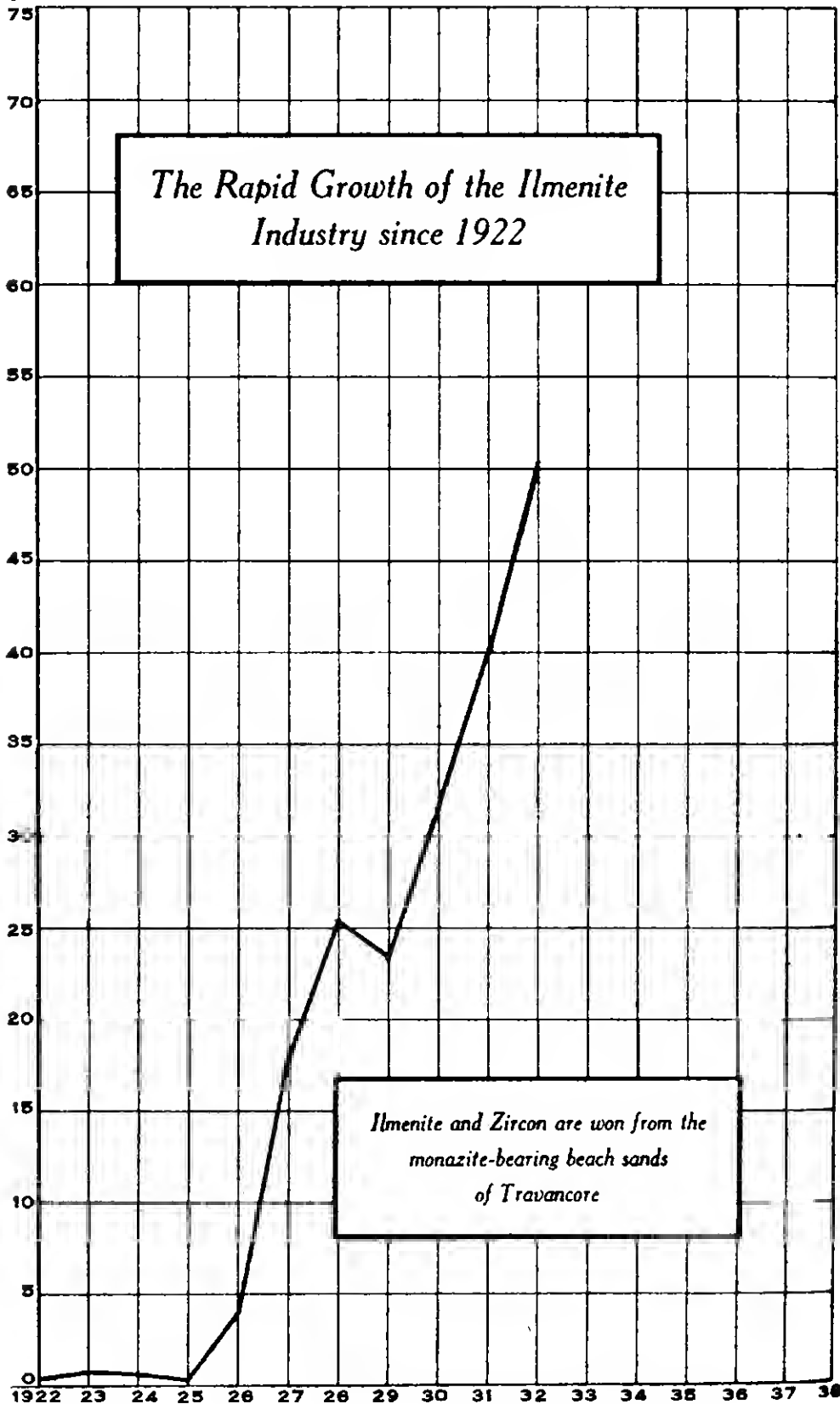
PERIOD	PRODUCTION		IMPORTS	AVERAGE ANNUAL	
	Madras	Rajputana		Consumption	Value
1918-22 ...	9,191	884	411	2,097	Rs. 51,352
1923-27 ...	4,167	6,186	4,696	3,010	97,732
1928-32 ...	15,022	7,232	17,083	7,867	2,21,616

The Madras production was entirely from the Kurnool district, with the exception of a total of 2,613 tons from the Cuddapah district in 1931 and 1932.

## ILMENITE

Ilmenite, the titanium-bearing iron ore, which may contain up to 31.6 per cent of titanium, is the chief constituent of many of the black sand concentrates derived from Indian rivers traversing areas of crystalline rocks, but the black sands of the Travancore coast, originally exploited for their monazite content, are the only sources of commercial importance at present. G. H. Tipper has shown that ilmenite accompanies monazite in the pegmatites which traverse the gneissic rocks of southern Travancore, and it probably occurs in the

THOUSAND  
TONS



*The Rapid Growth of the Ilmenite Industry since 1922*

*Ilmenite and Zircon are won from the monazite-bearing beach sands of Travancore*

Graph 17

gneisses themselves in addition. These minerals together with quartz, garnet and zircon are concentrated into certain patches of sand which lie along the shore from Nindikarai, north of Quilon, on the west coast, to Cape Comorin and thence up the east coast to Liparum, a distance of about 100 miles. Their accumulation, according to G. H. Tipper, proceeds at its greatest rate during the quiescent period of the north-east monsoon, when the sorting action of the waves is not interrupted by violent winds. The beach sand at present excavated by Travancore Minerals Ltd., whose works are at Manavalakurichi, is said to be about 8 feet thick and to contain 70 per cent of ilmenite. It is dried, screened, concentrated on tables and separated from zircon, monazite, rutile, garnet and various other minerals, transported by road to Kolachel, five miles to the west-north-west, and there shipped.

Specimens of titanium dioxide, or titanium white, made from Indian ilmenite were exhibited at the British Empire Exhibition in 1924. It is a valuable pigment, used either alone or in conjunction with zinc oxide, barite, gypsum or lithophone, which possesses a remarkable opacity and great covering power as well as anti-corrosive properties. It is non-poisonous and thus has an advantage over white lead in the manufacture of paints.

Ferro-titanium is also manufactured for use in the production of alloy steels, while nickel-cobalt-titanium alloys have special uses in mechanical engineering.

Commencing in 1922 with 400 tons, India produced 231,460 tons, valued at £ 292,864, up to the end of 1933. Progress has been rapid and output is expanding, being 75,644 tons in 1934.

In July, 1934, the Billingham works of the British Titan Products, where titanium white is manufactured, were formally opened. This new company has been formed by Imperial Chemical Industries Ltd., whose Billingham factory the new works adjoin; the Imperial Smelting Corporation Ltd.; Goodlass Wall & Lead Industries Ltd., and the National Lead Co. of America, which controls the oldest titanium pigment enterprises in America and Europe.

## CORUNDUM

Corundum is the natural oxide of aluminium and its clear coloured varieties form the ruby, sapphire and other precious stones. The opaque dull kinds are used as abrasive materials on account of their hardness, and the mineral is the most important of all the natural

abrasives. Its name is derived from the Hindi *kurand*, which is held to indicate that the stone became known in Europe from imported Indian specimens, for it has certainly been worked there from very early times. Sir Thomas Holland has shown how Indian armourers and lapidaries have used the mineral for many generations, obtaining their requirements from a few comparatively rich deposits, though it is at the same time doubtful whether these are worth working for export.

Statistics of corundum production in India are admittedly incomplete for they do not include the casual collections made by villagers, probably amounting to a considerable quantity in the aggregate, which reach the bazaars of the great cities where the lapidary still flourishes. In any case the output varies much from year to year. In 1909, 814 cwt. was returned and in 1913, 8,924 cwt., valued at £2,215, which came from Madras, Mysore and Rewah. The five years ending 1918 were probably the best that the Indian export trade in corundum has ever experienced, the average annual output being 24,534 cwt. From Assam alone over 40,000 cwt. was taken in 1917, most of which reached the United States of America and was used in fine optical grinding. It is not certain however that much sillimanite was not included in this material. Production ceased in both Assam and Rewah about 1921, and from that date until the end of 1934, a total of 44 tons has come from the Bhandara district of the Central Provinces between 1925 and 1927, and 154 tons from the Salem district of Madras, spread over the years 1926-30.

The massive sillimanite-corundum deposits of Sona Pahar in the Khasi hills of Assam are associated with biotite-sillimanite-cordierite-quartz rock and with sillimanite-quartz schists, intruded by veins of granite-gneiss. Further details of this occurrence are given under SILLIMANITE. The total production of corundum from this area, during the years 1916 to 1921 in which it was worked, was 6,645 tons.

The corundum quarries of Rewah State in Central India were supplying the mineral in 1814, and probably from a much earlier date. The earliest reference in European literature to them is dated 1820, and they were described by F. R. Mallet in 1872. The most recent account was given by J. A. Dunn in 1929. Near the village of Pipra there is a little hill which contains a 'bed' of massive, fine-grained, grey, purple or pink corundum, associated with sillimanite and hornblende schists, enstatite-bearing rocks and intrusive granite-gneiss of Archæan age. Dunn has estimated that there are 400,000

tons of corundum rock in this vicinity, including 100,000 tons of high grade mineral as well as 100,000 tons of sillimanite. The total recorded output from Rewah from 1901-02 to 1920-21 was 718 tons.

The massive corundum of Pohra in the Bhandara district of the Central Provinces comes from alluvial deposits derived from a small hill in which quartzites, sillimanite-quartz-muscovite schists and tourmaline rock occurs. According to Dunn the deposit is not likely to have a valuable future, though there is a possibility that other small ones may be found on some of the hills in the neighbourhood.

Crystalline corundum has a wide distribution in Southern India, most commonly in association with basic rocks containing pyroxene as a predominant constituent, together with some member of the spinel group of minerals. At the same time intrusions of pegmatite often occur in the vicinity of the corundum-bearing rocks. A great number of localities are listed from the Anantapur, Coimbatore, Salem and South Kanara districts. At Paparapatti in Salem, C. S. Middlemiss found it in lenticles of felspar, disposed in parallel bands along the strike of a series of foliated pyroxene-granulites. This band of lenticles has been traced by means of surface indications at intervals from Donnakuttahalli on the Cauvery to Chintalakuttai, a distance of nearly 40 miles.

Corundum of various grades and colours has been found at many localities in the Bangalore, Hassan, Kadur, Kolar, Mysore and Tumkur districts of Mysore, where it is usually obtained as broken crystals from the surface soil, having been freed from the underlying rocks by the processes of weathering.

In spite of the ever increasing use of artificial abrasives there is a steady demand for good grades of crystalline corundum, and it is difficult to understand why its mining, which has been made a profitable enterprise in South Africa, where geological conditions are not unlike those of Southern India, has hitherto completely failed to establish itself there.

### GARNET (ABRASIVE)

Red and brown garnets are common minerals in the crystalline rocks of the Indian peninsula and, when they possess the necessary transparency and are sufficiently free from flaws, are often cut as gem stones. Garnet is also used as an abrasive material, an application which it owes to its hardness and uneven fracture. Although garnet



is so prevalent in India there are few deposits of possible economic value known, and there is no regular trade in the mineral, in spite of the demand for the proper kinds. They are used for making garnet paper, cloth and discs, being crushed, classified and prepared in the same way as emery or corundum; the finished products being placed on the market in very similar forms. Abrasive garnet is employed mainly in the wood and leather trades for finishing purposes, and for these operations it is said to be indispensable, but the demand is a limited one and only capable of absorbing a few thousand tons annually. Loose, fine-grained material is used for surfacing plate glass. From time to time large quantities of garnet are reported as having been produced, presumably for these abrasive purposes, in the Tinnevely district of Madras. In 1914, 1,000 tons of garnet sand was so returned; in 1927, 285 tons; in 1928, 480 tons; while for the three years ending 1934 production averaged 222 tons per annum. Garnet sand is obtainable in large quantities from the sea beaches of Travancore, but the fine, water-borne material, with the sharp edges of the grains worn away, is not nearly so valuable as cleaned and graded garnet obtained from rock. As long ago as 1880, C. L. Griesbach drew attention to the isolated masses of garnet rock in the vicinity of Gobra hill and to the patches of the same material associated with hornblende and micaceous quartz schists between Rampur and Kapaut, Sarguja, Central Provinces. Near Sasiri, in Ajmer-Merwara, Rajputana, A. M. Heron in 1924 found upwards of fifteen irregular bands of massive, reddish-brown garnet, more than one foot in thickness. They occur in banded granulites interbedded with crystalline limestone. The largest band, 6 to 12 feet in width, forms an outcrop 15 feet high in places and can be traced for about 300 yards. Four-fifths of the whole of this vein is solid garnet, the remainder being quartz, calcite and country rock. Loose blocks, two or three feet across, of almost pure garnet, are strewn in dozens all along the outcrops of the chief bands. The locality is accessible and only five miles from the nearest railway. B. C. Gupta in 1934 recorded Aravalli schists thickly studded with garnet crystals from various localities in central Mewar. Those near Pur and Harnai Bari merit attention as they are easily approachable from the railway at Bhilwara. In the same year P. K. Ghose reported workable deposits of coarse garnet crystals near Korissa Konda, Nellore district, Madras.

## CHAPTER X

### MINERALS USED IN AGRICULTURE: SALTPETRE, OTHER POTASSIUM SALTS, PHOSPHATES AND AMMONIUM SULPHATE

#### SALTPETRE (POTASSIUM NITRATE)

MANY years ago, and for quite a lengthy period of time, India possessed a virtual monopoly of the world's supply of nitrates, which are essential for the manufacture of explosives and at the same time are invaluable as agricultural fertilizers. As the nitrates are soluble in water, they only occur in large quantities naturally under very exceptional circumstances, and India was displaced from her leading position by the exploitation of the vast deposits of sodium nitrate (Chile saltpetre) found in the rainless deserts of Chile. They in their turn have had to meet the competition of nitrates which are made in increasing quantities synthetically from the nitrogen of the air. Potassium nitrate is formed whenever organic nitrogenous substances decay in contact with potassium salts, the reaction being brought about by the work of nitrifying bacteria; thus, in temperate climates it occurs in the lime and plaster of old buildings, particularly near the ground, while the so-called 'nitre plantations' of some parts of Europe last century took advantage of the same process. Large heaps of manure and animal refuse interlaid with brushwood were built up and covered with wood ashes, old lime and other alkaline rubbish, constantly turned over and allowed to ferment for two or three years; the heaps, on lixiviation with water, gave solutions which on treatment with potash yielded saltpetre.

Sir Thomas Holland has shown how almost ideal conditions exist on the plains of Bihar for the formation of saltpetre. In this region there is a dense, agricultural population, using wood and cow dung as fuel, possessing large herds of cattle which supply abundant organic nitrogen, and living under climatic conditions in which high temperatures and humidity with a low diurnal range, combine to favour the propagation of the essential micro-organisms. As a result

the moisture which is constantly rising to the surface, leaves efflorescences at suitable seasons in which saltpetre is present, usually to the extent of about 5 per cent, but often more. The process of manufacture is simple and has been described repeatedly, since it was first outlined by Thevenot in the first volume of the *Philosophical Transactions*, published in 1665. His account, entitled 'Of the Way used in the Mogol's Dominions to make Saltpetre', shows that the methods followed over 270 years ago differ in no essential respect from the practice of today. The efflorescences are scraped from the surfaces of old mud heaps, mud buildings, the sites of deserted villages and the environs of existing ones. Treatment consists in lixiviation, evaporation, the addition of wood ashes to decompose any calcium nitrate present, and fractional crystallization. The crude saltpetre so obtained varies greatly in composition and is usually refined before export. In addition to the production from the districts occupying the Gangetic plain in Bihar, large quantities are made in the Cawnpore, Ghazipur, Allahabad and Benares districts of the United Provinces and in the Punjab. It was also manufactured at one time in the Anantapur, Coimbatore, Guntur, Kurnool, Madura and Nellore districts of Madras and in the Ahmedabad district of Bombay. It is still imported in large amounts from Nepal, and made on a small scale for the manufacture of gunpowder by the Kachin tribes of the Burma-China frontier. Crude nitrate-bearing earths are applied directly to the fields in parts of Bihar and in North-Western India, especially in the Upper Doab, while the consumption of saltpetre on the tea gardens of Assam and elsewhere amounts at present to about 700 tons per annum.

The manufacture of saltpetre in the old days was a monopoly of the East India Company, and the average annual exports during the years 1791 to 1805 amounted to approximately 80,000 tons. For the years 1876 to 1880, the average had fallen to some 21,000 tons, and it declined still further to 19,500 tons at the end of the century. The industry has always responded to the stimulus of war periods, and it is interesting to note that it reached its zenith at the time of the American Civil War, when the value of the exports ranged between £ 600,000 and £ 900,000 per annum. In the quinquennium before the Great War, the average annual exports had sunk to 16,440 tons, but the expected revival occurred and the next period of the same length witnessed an increase to 21,740 tons. Since then there

has been a rapid and continued slump, and for the past five years, ending 1933, exports have only averaged 6,467 tons. Exports for 1934 were 8,314 tons. Quite apart from the world depression of the past three years, it thus appears that synthetic nitrates and natural fertilizers from other countries are now being sold at prices with which Indian saltpetre is finding it increasingly difficult to compete.

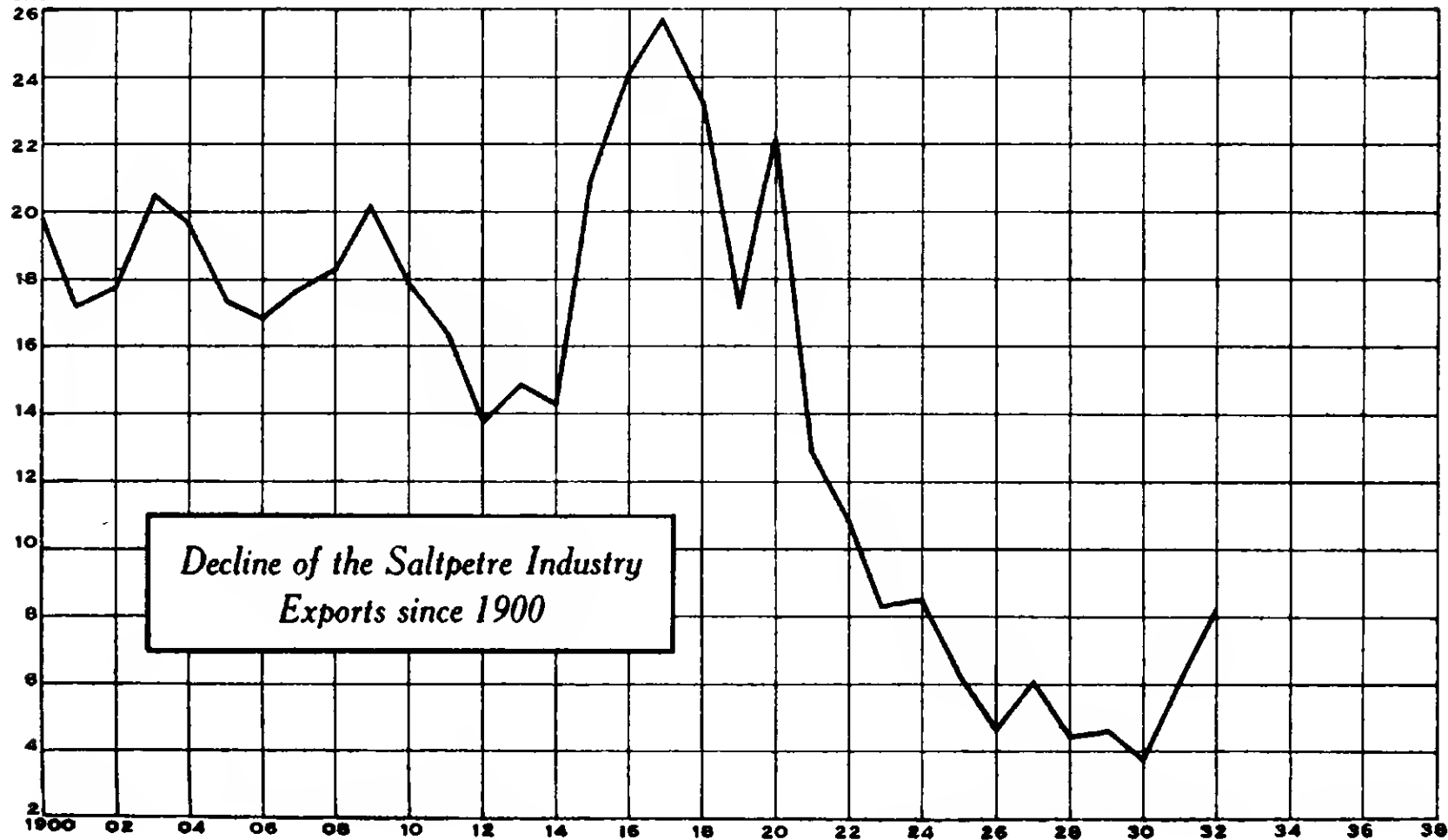
As the returns of production have not always been reliable and have indeed ceased entirely since 1924, the statistical tables which follow are based on export returns and on figures issued by the Northern India Salt Revenue Department.

Table XXIV is a statement of the imports of saltpetre into Calcutta from 1897 to 1923 and shows the variation in the amounts contributed by the various provinces. Bihar commenced with nearly 60 per cent, fell to nearly 25 per cent in the war period, but recovered to over 36 per cent. The United Provinces, after some variation, remain about where they started, while the Punjab increased from 11 per cent to over one-third of the total.

The total exports of saltpetre between the years 1897 and 1933 were 530,018 tons, valued at £ 9,784,791 (see Table XXIII). In the first part of the period the United Kingdom took 30 per cent of the exports and Hong-Kong and the United States of America followed with 25 and 24 per cent respectively. Excluding the war period when three-quarters of the total reached the United Kingdom, there was not much variation in the British trade until the period 1924-28 when the amount fell to 13 per cent. The latest figures for 1929-33 indicate a return to the former proportion of the greatly diminished available quantities. The trade with the United States never recovered from its war-time diversion and has disappeared again; much the same applies in the case of Hong-Kong. On the other hand, exports to Ceylon have increased from 2 per cent to 33 per cent (60 per cent in 1924-28), and to Mauritius from 6 per cent to 29 per cent. In actual quantities Mauritius for the period ending 1928, before the world depression affected trade, bought considerably less than half the 1897-1902 amount, while the Ceylon purchases were nearly nine times as great as they were then. The export trade has always centred around Calcutta, which still commands almost 95 per cent of the total.

THOUSAND

TONS



Graph 18

**TABLE XXIII**  
**INDIAN SALTPETRE EXPORTS AND THEIR DESTINATIONS<sup>1</sup>**

PERIOD	TOTAL TONNAGE	VALUE	UNITED KINGDOM	HONG-KONG	UNITED STATES OF AMERICA	MAURITIUS	FRANCE	STRAITS SETTLEMENTS	CEYLON	JAPAN	OTHERS	EXPORTED FROM		
												Calcutta	Bombay	Karachi
1897-98 to 1902-03	114,706	£1,575,552	%30·7	%25·7	%24·0	%6·3	%6·0	%2·6	%2·0	%1·4	%1·3	%98·5	%...	%...
1903-04 to 1907-08	89,747	1,326,675	25·0	22·1	32·8	6·3	6·1	2·8	2·8	...	2·1	98·6	...	...
1908-09 to 1912-13	82,882	1,263,170	19·2	23·7	27·2	12·4	2·9	3·0	7·7	...	3·9	98·4	...	...
1914-18	108,685	2,588,950	76·8	3·7 <sup>2</sup>	7·0	2·3	...	...	4·7	2·4	3·1	78·4	7·6	14
1919-23	71,358	1,986,352	29·9	15·2	9·2	18·0	...	...	19·5	0·9	7·3	88·4	2·3	9·3
1924-28	30,305	636,105	13·4	10·2	...	9·8	...	3·7	59·9	...	3·0	94·9	4·1	1·0
1929-33	32,335	407,987	29·2	...	...	29·1	...	2·1	33·5	...	6·1	...	...	...
<b>GRAND TOTAL</b>	<b>530,018</b>	<b>£9,784,791</b>	...	...	...	...	...	...	...	...	...	...	...	...

<sup>1</sup> Expressed as percentages of the total trade.

<sup>2</sup> To China.

SALTPETRE

TABLE XXIV

IMPORTS OF SALTPETRE INTO CALCUTTA BY LAND<sup>1</sup>

PERIOD	TOTAL TONN- AGE	BIHAR	UNITED PRO- VINCES	PUNJAB	RAJPUTANA AND CENTRAL INDIA	OTHERS
		%	%	%	%	%
1897-98 to 1902-03	116,922	59.1	29.2	11.3	0.4	...
1903-04 to 1907-08	94,895	56.1	28.6	14.4	...	0.9
1908-09 to 1912-13	88,096	58.0	30.8	10.8	...	0.4
1914-18 <sup>2</sup> ...	104,745	26.6	40.6	31.5	1.3	...
1919-23 <sup>2</sup> ...	72,710	36.6	28.2	33.9	1.3	...

TABLE XXV

IMPORTS OF SALTPETRE INTO  
INDIA FROM NEPAL

PERIOD	TOTAL TONNAGE
1897-90 to 1902-03	2,825
1904-05 to 1907-08	1,035
1908-09 to 1912-13	2,293
1914-15 to 1918-19	1,148
1919-20 to 1923-24	996

## OTHER POTASSIUM SALTS

Potassium-bearing minerals were discovered in the Mayo mines of the Salt range by H. Warth, in 1873, which on examination by G. Tschermak and F. R. Mallet proved to consist of mixtures of common salt and magnesium sulphate or kieserite ( $\text{MgSO}_4$ ,  $\text{H}_2\text{O}$ ), with sylvite, potassium chloride ( $\text{KCl}$ ), and langbeinite, a double sulphate of potassium and magnesium ( $\text{K}_2\text{SO}_4$ ,  $2\text{MgSO}_4$ ). Only about half a ton of the mixture was obtained from a single lenticle.

Potassium salts are of great economic importance, particularly for agricultural purposes which are estimated to consume 90 per cent of the world's output; and for many years practically the whole supply was derived from mines in northern Germany. In 1913, W. A. K. Christie investigated the Salt range occurrences, and in the Mayo mines alone, 21 places were found in which potassium-bearing minerals occurred. Many of these were too small to be of any

<sup>1</sup> Showing provincial percentages of production.

<sup>2</sup> The figures for these years are production returns.

commercial value, while others revealed the existence of three seams which appeared to thin out when followed upwards. The amount of potash, calculated as  $K_2O$ , in the visible portion of the uppermost seam, was estimated at 3,000 tons, while the percentage of potash in the average samples taken varied from 6.8 to 14.4 per cent. Another bed, about six feet thick, was found in the Nurpur mine, and it contained 13.6 per cent  $K_2O$ . In addition to the minerals mentioned above, kainite ( $KCl, MgSO_4, 3H_2O$ ) was recognized at this time.

Murray Stuart examined the salt deposits of the Punjab Salt range and of Kohat, with special reference to the occurrence of potassium-bearing minerals, in 1915–17. He found two distinct seams in the Nurpur mine but added, 'not only do the potash bands vary abruptly in thickness and direction, but they vary throughout their length in the percentage of potassium in them'. Potash was also found to occur in three chambers of the Warcha mine, but these deposits were not regarded as promising. Stuart's conclusions were summarized as follows: 'On the whole the evidence collected during my investigations points to the conclusion that no continuous bed of potash will be found in the Salt range or in Kohat. The salt is a foliated rock and the potash salts occur in discontinuous lenticles and irregular foliæ. Where the foliation is of the nature of banding, bands of potash may persist for some little distance, but even then they will probably thicken and thin throughout their length. The prospects of obtaining potash in the Salt range are not therefore promising, and it is not likely to be worked profitably except as a by-product of salt-mining.'

P. K. Ghose showed in 1934 that the *reshta* or powdery salt which collects along the margins of the salt pans of Lake Sambhar, Rajputana, during the hot months of the year, has a fairly high potassium content. In two samples analysed by him the average of the potash ( $K_2O$ ) content was 7.74 per cent.

In addition to their uses as fertilizers—and potassium salts are essential to plant life—they find many other applications in industry and are employed in the manufacture of explosives, gunpowder, fireworks and matches, particularly potassium chlorate. Potassium cyanide is used in the extraction of gold from its ores; the chromates and dichromates in tanning and dyeing; while other salts find an outlet in the manufacture of glass and soap, in photography and pharmacy, though this by no means exhausts the list of their utilities.



The average annual imports of potassium salts into India for the five years ending 1932-33 were as follows.

*TABLE XXVI*  
IMPORTS OF POTASSIUM SALTS  
1928-29 TO 1932-33

				AVERAGE ANNUAL	VALUE
				<i>Tons</i>	<i>Rs.</i>
Potassium	Chloride	...		5,320	6,31,365
"	Chlorate	...		1,981	8,07,602
"	Bichromate	...		261	1,63,741
"	Cyanide	...		11	19,730
Others	...	...		809	4,78,464
Total				8,382	21,00,902

### PHOSPHATES

Phosphorus, like nitrogen, is an element which is essential to plant life. The Royal Commission on Agriculture (1928) found that the laterite soils of India, especially those of the peninsula and Burma, which have been devoted to paddy growing for generations, were particularly deficient in phosphates, and there are nearly 80 million acres under rice in India, representing over 35 per cent of the total land under cultivation. Experiments with phosphatic manuring have had very beneficial effects, and in 1929 the Tariff Board, after its examination of the leading specialists in these matters, reported to the Government of India that while a combination of organic manures with superphosphate gives the best return, by the use of the latter alone the productivity of the soil has been increased by 30 to 40 per cent. As regards artificial fertilizers alone—and they are of great value for paddy, sugar-cane, tea and rubber—the best results are obtained by the combined application of nitrogen and phosphoric acid in a soluble form. The great majority of the population of India is occupied directly or indirectly in agriculture, and the chief obstacle to the improvement of Indian agriculture is the lack of manure. 'Water and manure together,' writes Dr. Voelcker,<sup>1</sup> 'represent in brief the ryot's main wants.' According to J. W. Mollison, late Inspector-General of Agriculture, 'a great deal of land, particularly in the

<sup>1</sup> *Improvement of Indian Agriculture*, chap. vii.

poorer tracts of peninsular India, is slowly undergoing exhaustion for lack of manuring, yet the deposits of the mineral phosphates which might form the basis of mineral fertilizers remain unworked, and immense quantities of phosphates and other fertilizers in different forms are exported every year'.<sup>1</sup>

*Superphosphate.* The world's production of superphosphate now amounts to about 14 million tons per annum. The raw materials required for its manufacture are sulphuric acid and bones, or natural phosphates, the calcium phosphate in them being converted by the acid into a form more readily assimilated by plants. Immense quantities of bones, mainly crushed, or in the form of meal, have been and are still shipped from India to other countries. The annual quantity concerned at present may be taken as roughly 100,000 tons a year, worth over a crore of rupees in normal times, and the investigations of the Tariff Board have shown that 'they command a higher price in foreign markets for use in the preparation of commodities other than artificial manure than is charged for rock superphosphate in India. The balance of advantage therefore appears to lie in the export of bones and the purchase or manufacture of rock superphosphate. Indeed a reduction in the price of bones of at least Rs. 30 or Rs. 40 a ton is necessary before the manufacture of bone superphosphate in India becomes a practical proposition.' Thus, although small quantities of bone superphosphate have been made by chemical manufacturers in Calcutta, Madras and Bombay, the industry appears unlikely to expand under existing conditions and the country is left with its rock phosphates as a potential raw material.

*Apatite.* Apatite is a mineral phosphate of calcium containing either fluorine or chlorine, or both these elements in addition, in which the percentage of phosphorus pentoxide may vary between 41.0 and 42.3 per cent. It occurs associated with chlorite, magnetite and other iron ores in innumerable veins along a belt of country in the Singhbhum district of Bihar and Orissa, stretching for twelve miles from Patharghara through Mosaboni, Badia, Kanyaluka and Sungri, south-east to Khejurdari, parallel and close both to the Subarnarekha river and the Bengal-Nagpur railway. The apatite-magnetite rock, according to L. L. Fermor, is in the form of lenses in Dharwarian schists, varying in size from 90 feet long, by 24 feet thick,

<sup>1</sup> *Imperial Gazetteer*, III, p. 21.

through lenses 2 or 3 feet long and 1 foot wide, to small lenticles, separate granules and disseminated crystals. The apatite belt lies on either side of that of the ancient copper mines, and the magnetite-apatite rocks are regarded as pneumatolytic introductions from the intrusive granite of the vicinity. In Dr J. A. Dunn's opinion however, the apatite-magnetite veins and the closely associated copper lodes are liquations from the soda-granite magma which ascended along the thrust plane of this part of Singhbhum. The vein materials themselves form fine to medium grained aggregates suggestive of crystallization from an injected melt. In the copper belt as a whole, Dunn found practically no apatite west of Dakidih, a maximum development near the mylonitized granite of Kudada, few occurrences between Rakha and Surda, and many examples within the granite to the south of the latter place, while it is also present around Sungri. A concession over certain occurrences at Sungri, Kanyaluka and Badia was obtained during the Great War by the Great Indian Phosphates Ltd., and passed after the liquidation of that concern to a private syndicate. The reserves are estimated at between 100,000 and 200,000 tons, and the material averages 20 to 25 per cent phosphorus pentoxide before magnetic separation, and 35 per cent afterwards.

Deposits at Patharghara and Mosaboni were worked for some years by the Bengal Iron Co. Ltd., the ore being blended with other iron ores for the manufacture of phosphoric pig iron for foundry purposes. About 21 miles north-west of Patharghara and apparently forming a continuation of the same belt, there is a further occurrence at Nandup,  $2\frac{1}{2}$  miles south of Tatanagar railway station. In one zone, of which there are said to be several hereabouts, there is an average width of 50 feet of apatite, with granite and mica schist partings for 300 feet, and of this two-thirds consists of apatite. In this area the reserves of phosphatic ore of an average grade of 20 to 25 per cent phosphorus pentoxide are at least a quarter of a million tons and probably much more.

The largest vein at Kudada is 300 yards long and 10 feet wide. All the veins which have been worked are, according to J. A. Dunn, associated with chlorite schist in close proximity to a tongue of granite schist, but later shearing and thrust movements have destroyed their original forms of lens-shaped segregation veins and have caused them to become sheared, disjointed and contorted.

Apatite rock, which is used in iron smelting, appears in the returns with iron ores, and in the following table only that material is included which is believed to have been used in the manufacture of fertilizers.

**TABLE XXVII**  
**TOTAL PRODUCTION OF PHOSPHATE**  
**ROCK IN SINGHBHUM**

PERIOD	SUNGRI AREA		NANDUP AREA	
	Tons	Rs.	Tons	Rs.
1918 ...	5,100	...	...	...
1919-23 ...	1,929 <sup>1</sup>	19,240	5,020 <sup>2</sup>	87,000
1924-28 ...	4,597 <sup>3</sup>	...	8,610	1,42,370

Apatite occurs as an accessory mineral in the mica-bearing pegmatites of the Hazaribagh district, Bihar and Orissa, and of the Nellore district, Madras; in the mica peridotites of the Raniganj and Giridih coalfields; in the rocks of the Kodurite series of Vizagapatam; and in certain schists of the Dungarpur State, Rajputana, but none of these are of any utility as sources of commercial phosphates.

*Other Phosphates.* In addition to these definite mineral phosphates, such as apatite and triplite (a fluor-phosphate of iron and manganese which has been found at Singar, Gaya district, Bihar and Orissa), deposits of amorphous rock phosphates of lime of indefinite chemical composition and organic origin occur in various parts of the world. They are of great economic importance, upwards of 12 million tons being now mined annually, particularly in the United States and North Africa. India has its representatives of this group in the phosphatic nodules discovered by Wynne in the shales above the coal seams at the Dandot colliery, Jhelum district, Punjab; in the phosphatic rock and nodules from

<sup>1</sup> Three years only. No production in 1920 and 1922.

<sup>2</sup> Two years only. No production before 1922.

<sup>3</sup> Two years only. No production after 1925.

No production was recorded from Singhbhum for the years 1929, 1931, 1932 and 1933. In 1930, 22 tons, valued at Rs. 3,300, was returned.

Mussoorie, analysed by Mallet in 1885, and in the nodules found in the cretaceous rocks of Southern India. Regarding the latter Sir Thomas Holland has made the following statement: 'Among the phosphatic deposits of India, is the deposit of phosphatic nodules of the septarian kind, occurring in the Cretaceous beds of the Perambalur taluk, Trichinopoly district, Madras. Dr H. Warth estimated in 1893 that to a depth of 200 feet the beds contained nodules to the amount of eight million tons, but the phosphates are distributed irregularly through clay, varying, in the different excavations made, between 27 and 47 lb. per 100 cubic feet. Analyses of these nodules show them to contain from 56 to 59 per cent of phosphate of lime with about 16 per cent of carbonate. Two attempts made to dispose of these phosphates in a finely powdered condition for use as a fertilizer on coffee plantations in Southern India were, however, reported to be unprofitable.' Later efforts to find a market in Ceylon and further overseas still, by displaying specimens at the British Empire Exhibition in 1924, were also unsuccessful, though small parcels continue to be removed periodically, presumably for experimental purposes. The clue to their origin is given by an occurrence in Pondicherry, where Warth noticed in a sandy shale of the same age, several feet thick and full of the casts of shells, 'a wholesale conversion of shells into phosphate, or rather the production of interior casts of shells consisting of rich black phosphate'. Irregular phosphatic concretions are also found in the same bed. The phosphates which are dissolved in the sea water are absorbed into the shells of marine animals. The calcium carbonate with which they are associated in the shelly structures is more freely soluble, and a concentration of the phosphate can thus take place. At the same time such phosphates as are dissolved are redeposited around nuclei forming nodules and concretions. (Phosphatic concretions are often found on the ocean floor and G. H. Tipper has described examples from the Andaman sea.) After elevation above sea level, marine sediments containing phosphatic deposits may undergo further concentration by atmospheric agencies, the surplus calcium carbonate is dissolved and removed, and the less soluble phosphates left behind in a more or less impure condition.

Another possible source of phosphatic material for use in Indian agriculture is the basic slag made by the Tata Iron & Steel Co. Ltd. at Jamshedpur. The output of such slag, according to Sir

Edwin Pascoe, is some 40,000 tons annually (250–300 lb. of slag per ton of finished steel) and its phosphorus content varies considerably, but averages about 10 per cent  $P_2O_5$ . A small quantity is used in bringing up the phosphorus content of raw materials required by the tin plate industry to required standard, and the rest is dumped. Basic slag consists largely of lime and phosphoric anhydride, both of which are valuable to the agriculturist. It is suitable for sour, peaty and clayey soils, and is ground into a very fine powder before application. The phosphorus is present in a readily soluble tetra-basic form and is easily assimilated by plants. There are several grades on the market, the values of which depend entirely upon the amount of phosphorus present in them. As Indian basic slag has a considerably lower percentage than the cheapest of these grades, its utility is doubtful, but it has been suggested that by amelioration with apatite a profitable fertilizer might be produced.

The problem of the utilization of Indian rock phosphates demands more research than it appears yet to have received. The Tariff Board as a result of its inquiries estimated the consumption of superphosphate in India in 1929 at, approximately, 10,000 tons and anticipated a rapid increase in the demand. As the Board then stated: 'It is anomalous that a country in which 90 per cent of the inhabitants are agriculturists should have to depend on foreign imports for such an important adjunct to agriculture as artificial manure.' The actual imports of manures, excluding oil cake, into India, for the five years ending 1932–33, averaged 57,474 tons per annum, valued at Rs. 65,69,955, and but for the depression would unquestionably have been much larger, as the imports in 1931–32 (34,097 tons) were less than half those of 1929–30 (78,316 tons). Analysing the trade figures it is found that nitrogenous manures, including ammonium sulphate and sodium nitrate, accounted for 51 per cent of the total; potassium compounds for 10 per cent; phosphatic manures for 32.6 per cent; while the remaining 6.4 per cent was made up largely of fish manures, ammonium phosphate (in small amounts) and other substances. The classification adopted in the official returns is not entirely satisfactory, as the returns prior to 1931–32 seem to include under 'phosphatic' materials, artificial and mineral manures of a different chemical character.

## AMMONIUM SULPHATE

The most important nitrogen-bearing fertilizers, from which this essential element is supplied to plants to augment the quantities they obtain naturally from the soil and air, are sodium nitrate (saltpetre or nitre), cyanamide (an artificial product) and ammonium sulphate, which is produced by the action of sulphuric acid on ammonia. The Royal Commission on Agriculture found that all Indian soils were generally deficient in nitrogen, a result largely of the failure of the ryot to utilize green and farmyard manures, intensified by the heavy rainfall which removes large quantities of soluble nitrogenous compounds. The world's annual production of pure ammonium sulphate now averages about four million tons per annum, rather more than half of which is made by the synthetic process, using the nitrogen in the air as a starting point, and the remainder as a by-product in the coking of coal, the ammonia in the gases from the coke ovens being removed by sulphuric acid. The latter is the only process used in India. The first by-product recovery coke ovens in India were started at the East Indian Railway Co.'s colliery on the Giridih coalfield in 1909, and at that time the annual production of ammonium sulphate amounted to some 400 tons per annum. Further installations followed as time went on, and there are now nine important producers in Bengal and in Bihar and Orissa. Statistics relating to the substance in recent years are summarized in the following table.

TABLE XXVIII

## TOTAL PRODUCTION, IMPORTS, EXPORTS AND CONSUMPTION OF AMMONIUM SULPHATE

PERIOD		PRODUCTION	IMPORTS	EXPORTS	CONSUMPTION
		<i>Tons</i>	<i>Tons</i>	<i>Tons</i>	<i>Tons</i>
1919-23	...	21,707	879	18,368	4,218
1924-28	...	78,593	24,145	25,330	77,408
1929-33	...	65,190	116,662	9,517	172,335

Unfortunately for India most of her ammonium sulphate has gone in the past to enrich the plantations and fields of Java, Ceylon,

Mauritius and Japan, where its value to agriculture was better appreciated. The position appears, however, to have improved in later years, for the above figures show that although the greater amount was shipped abroad in the first period quoted, the exports during the next five years amounted to less than a third of the output, while the imports nearly balanced the losses. In the last period there has been a very marked increase in the imports. In addition to this, large and increasing quantities of cyanamide, nitrolim and other artificial nitrogenous fertilizers, which do not concern us here, are being imported to supplement the supply. The decrease in the home output in more recent years is due to stagnation in the coal trade as a consequence of the world depression. The demand for ammonium sulphate is a growing one, and provided it can be supplied at prices which the Indian cultivator can afford, very large quantities indeed should be absorbed in the future.



## CHAPTER XI

### MINERALS USED IN INDUSTRY GENERALLY: SULPHUR AND SULPHURIC ACID, IRON SUL- PHATE, COPPER SULPHATE, SALT, OTHER SODIUM COMPOUNDS, BORAX, MAGNE- SIUM CHLORIDE, BAUXITE, ALUM AND RELATED SUBSTANCES, STEATITE AND KAOLIN

#### SULPHUR

THE largest known occurrence of native sulphur in the Indian Empire is that near Sanni, in the Kachhi district of the Kalat State of Baluchistan, which was at one time worked for the amirs of Afghanistan. The mines were visited by Capt. Hutton in 1846, but were maliciously set on fire in the 'seventies and have remained closed ever since. According to G. de P. Cotter who examined their remains in 1919, the sulphur impregnates sandy clays which may be of Siwalik age, and has probably been deposited over a more or less circular area by a fumarole or a mineral spring. He estimated the reserves at about 36,000 tons of rock, averaging 28·8 per cent of sulphur, a quantity which would not suffice the Indian sulphuric acid manufacturers for a normal year's supply.

Small amounts of the element have been formed as a result of solfataric action on the volcanoes of the Koh-i-Sultan in Baluchistan and Barren Island in the Bay of Bengal, but it is extremely doubtful whether these and a few other reported occurrences in India proper are worth working.

Sulphur, the natural sulphides, and particularly pyrite, the sulphide of iron, are the principal raw materials used in the manufacture of sulphuric acid, but before considering the economic position of its manufacture in India it may be noted that sulphur has many other outlets. Thus it forms an essential ingredient of gunpowder and of certain blasting powders. It is employed in the making of matches

and fireworks. In the preparation of wood pulp to be made eventually into paper, large quantities of sulphur are taken. The rayon industry needs it in the form of carbon disulphide, and it forms the vulcanizing agent for rubber. As an agricultural and horticultural fumigant and insecticide it is well known, and smaller quantities find their way into the tanning and glue-making trades, as well as into pharmacy. Sulphur is sometimes used directly for the industrial preparation of sulphuric acid, but the basic material of many plants in many countries is pyrite, iron disulphide ( $\text{FeS}_2$ ). No extensive deposits of pyrite have as yet been found in India. The mineral occurs in shales associated with the Tertiary coal measures of Assam and the Punjab, and in the Eocene alum shales of the Salt range, Cutch, Sind and other places. It has been found in Hyderabad, Mysore, Rajputana and the Shan States; indeed, it is a common mineral in small quantities practically everywhere, but not in amounts of any industrial value. An occurrence near Polur, North Arcot district, Madras, was opened up by the Geological Survey of India in 1926, and the mineral proved to be present with pyrrhotite, in lenticular patches up to  $4\frac{1}{2}$  feet thick, between basic charnockites and quartzites, presumably of Dharwar age.

Large quantities of sulphuric acid are made in some countries from the sulphur dioxide liberated in the roasting of lead, copper and zinc ores before the metals are extracted from them. The sulphur contents of the lead ores smelted at Nam Tu and of the copper ores treated at Mosaboni are at present waste products. It has been stated however, that the character of the copper ore concerned is such that though the manufacture of sulphuric acid from it is theoretically possible, no process is known at present which would make it a commercial success. Moreover, in the case of galena, the natural sulphide of lead, the amount of sulphur present is only 13.4 per cent, compared with 33 per cent in the corresponding zinc compound. As a general approximation it may be taken that one ton of sulphuric acid of the strength usually made in India, could be made from one ton of Burmese zinc concentrates, the exact amount obtainable of course being dependent on the composition of the concentrates themselves and the density of the finished acid. As shipped in 1932, the composition of these was 51.6 per cent of zinc and 6 per cent of lead, compared with an average of 63.6 per cent zinc and 4.2 per cent lead in 1931. The average annual export is now about 55,800

tons, and has been up to 64,100 tons. An idea of their potentialities as a source of sulphuric acid may be obtained from these figures. The proposal made in 1919-20 to smelt the zinc ore in India and recover sulphuric acid as a by-product was abandoned, and the Indian supplies of the acid are made entirely from imported sulphur which at present is mainly of Sicilian origin.

'Sulphuric acid,' wrote Sir Thomas Holland, thirty years ago, and his words are equally weighty today, 'is the key to most chemical and many metallurgical industries; it is essential for the manufacture of superphosphates, the purification of mineral oils and the production of ammonium sulphate, various acids and a host of minor products; it is a necessary link in the chain of operations involved in the manufacture of the alkalis which are bound up with the industries of making soap, glass, paper, oils, dyes and colouring matters; and as a by-product it permits the remunerative smelting of ores which it would be impossible otherwise to develop.' The statistical position from that time onwards is summarized below:

TABLE XXIX  
TOTAL IMPORTS AND PRODUCTION OF  
SULPHUR AND SULPHURIC ACID

PERIOD	IMPORTS		PRODUCTION
	Sulphur	Sulphuric Acid	Sulphuric Acid
	<i>Tons</i>	<i>Tons</i>	<i>Tons</i>
1898-1903 <sup>1</sup> ...	10,240	13,612	...
1904-08 ...	15,858	15,742	...
1909-13 ...	25,650	15,947	...
1914-18 ...	39,005	1,980	...
1919-23 ...	42,345	912	64,175 <sup>2</sup>
1924-28 ...	78,962	588	142,128 <sup>2</sup>
1929-33 <sup>3</sup> ...	86,977	2,245	...

The oldest manufacturers are Messrs D. Waldie & Co., whose chemical works were established at Konnagar, near Calcutta, over 75 years ago. Other firms engaged in the industry, omitting coal, oil, gas, iron and steel producing companies and numerous smaller concerns, include the Bengal Chemical & Pharmaceutical Works,

<sup>1</sup> Total for six years.

<sup>2</sup> Reckoned as 100 per cent acid.

<sup>3</sup> Fiscal years.

Calcutta, where manufacture commenced in 1907; Parry & Co., Madras (before 1909); Burma Chemical Industries Ltd. (1910); the Eastern Chemical Co. Bombay (1913); and Dharamsi Morarji & Co., Bombay. An analysis of the total of 142,128 tons of acid made in India over the years 1924-28 shows that 51.2 per cent of it was made by coal, iron and steel companies in Bengal and Bihar and Orissa; 20.8 per cent in Burma; 1.5 per cent by the Government Cordite Factory in the Nilgiri hills; and the remaining 26.5 per cent by chemical works whose contribution to the output was distributed in the following proportions: Bombay, 12.3 per cent; Bengal, 7.2 per cent; the United Provinces, 3.4 per cent; Madras, 2.7 per cent; and the Punjab, 0.9 per cent. This widely scattered distribution of production leads to the quotation here of a conclusion of the Indian Tariff Board after its investigation of the heavy chemical industry in 1929, which is not without its bearing on the sulphuric acid problem: 'We wish to state definitely that in our opinion the chemical industry in India can have no future so long as manufacture is carried on in small units with low production.'

The world's annual production of sulphuric acid is now in the neighbourhood of 10 million tons per annum, of which this country supplies only a small fraction of one per cent. The truth of a remark by a writer on this subject (C. S. Fox) is at once apparent: 'If the demand for sulphuric acid is taken as the chemical barometer of industrial conditions, industrial activity in India is in its infancy.'

Seventy-five per cent of the world's annual output is believed to be consumed in the preparation of the fertilizers, ammonium sulphate and the acid phosphate of calcium known as superphosphate. The coal companies in India use their acid to make ammonium sulphate, by its reaction with the ammonia liberated during the coking process. Large quantities are also accounted for in the pickling of steel sheets during the galvanizing process. (The present production of galvanized sheets in India, according to the Tariff Board, is about 17,000 tons per annum (1929) while the market is about 350,000 tons.) The Burmese-made acid finds its main outlet in the petroleum refineries near Rangoon. A certain proportion made by chemical works proper is sold in the form of raw acid to the various trades in which it is employed. The quantity was estimated by the Tariff Board in 1929 as about 4,000 tons of rectified oil of vitriol (excluding Burma). Smaller amounts are used in the manufac-

ture of nitric and hydrochloric acids. Several heavy chemicals in the production of which the acid plays a direct part are now manufactured to some extent in India, though in very much smaller quantities than they are imported. Glauber salts, a hydrated form of sodium sulphate, used extensively in the textile industry and in pharmacy, are prepared from salt cake, itself an essential chemical in the manufacture of glass, the residue left after the treatment of common salt with sulphuric acid for the preparation of hydrochloric acid. Epsom salts, the sulphate of magnesium, are made by dissolving magnesite in sulphuric acid and used for sizing cotton fabrics and in medicine. Copperas, the hydrated ferrous sulphate, is formed by dissolving scrap iron in sulphuric acid and utilized in the manufacture of ink and in the paint industry. Copper sulphate is a valuable fungicide; aluminium sulphate, alum and aluminoferric are described elsewhere.

Without cheap and abundant supplies of sulphuric acid, India will never attain the position which her wealth of raw mineral products gives her a right to anticipate, but in the metallic sulphides of Bawdwin and elsewhere there is a sulphur reserve available if and when it is required. It is also possible, as a result of researches announced in England in 1935, that the gypsum deposits may at some future time supply sulphur for sulphuric acid manufacture.

### SULPHATES OF IRON AND COPPER

Melanterite or copperas, the pale green, hydrated sulphate of iron ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ), is a common decomposition product of iron pyrites and occurs as an efflorescence on pyritous or alum shales, from which it was at one time collected for sale. It was also obtained as a by-product from the mother liquors of the Indian alum works, but supplies from such sources have for all practical purposes ceased long ago owing to the competition of imported supplies. Small quantities, varying from 3 to 15 cwt., appear in the mineral returns for the years 1925-28, as a product of the Khardang mine in the Ladakh tehsil of Kashmir. The India of the past used the crude iron salt in combination with certain vegetable juices to produce various dyes of dark shades required by weavers and tanners. Today it is mainly employed in the manufacture of paint and ink. Fairly large quantities are now made in India by the action of sulphuric acid on scrap iron, the annual total being estimated at 958 tons by the Tariff Board in

1929, while the imports averaged 174 tons per annum for the five years ending 1932-33.

Copper sulphate, chalcantite, or blue vitriol ( $\text{CuSO}_4, 5\text{H}_2\text{O}$ ), is sometimes found as a decomposition product of copper ores. For many years it was manufactured, together with alum and copperas, from the decomposed slate and refuse of the copper mines of Khetri and Singhana, in Jaipur State, Rajputana. The insignificant quantities of natural copper sulphate obtained in India today come from abandoned copper mines such as those mentioned, or of the Letpandaung in the Chindwin valley of Burma, where it is still collected. The efflorescences which grow on the walls of the old workings are scraped off and dissolved in water, which after evaporation yields a mixture of crude sulphates of copper, iron and aluminium. Copper sulphate finds its main use in India as a fungicide, particularly on tea and rubber plantations. The Tariff Board estimated that the Indian production (from metallic copper and sulphuric acid) in 1929 was 35 tons per annum, while the imports for the five years ending 1932-33, averaged 1,041 tons per annum.

## SALT

India's salt production now averages about  $1\frac{1}{2}$  million tons per annum and this is probably insufficient for the normal physiological requirements of the population, without considering the quantities required by various industries. The balance is obtained by imports from foreign countries, and these now average about 600,000 tons per annum. The average annual consumption of salt in India, though more or less stationary for the decade preceding and including the war, and in spite of a slight diminution in the period 1924-28, has increased from 1,410,000 tons about the early years of the century to 2,010,000 tons today (see Table XXX). Though salt finds its main use in India in food, in other countries it is one of the most important raw materials in chemical manufacture, and is the starting-point for the preparation of hydrochloric acid, sodium carbonate, sodium sulphate and a vast array of other substances (including glass) which they in their turn yield. An American authority has calculated recently that the people of the United States, where the output is now over eight million tons per annum, employ about 16 times as much salt per person as the Chinese do, and although salt is taxed in China, as it is in India, this great difference is essentially due to the

chemical uses of salt in America. Any great expansion of salt manufacture in India will only arise for the same reason.

Thirty years ago India obtained over half of her external salt requirements from the United Kingdom and 13 per cent from Germany; the remainder being drawn from Aden (11 per cent), Arabia (10 per cent), and Egypt (6·5 per cent). The imports from the United Kingdom have gradually fallen, and today represent little more than 7 per cent of the supplies; Germany still sends 10 per cent, and while the trade with Arabia ceased nearly 20 years ago, that with Aden has slowly increased until it now accounts for 42 per cent of the imports. Egypt, after obtaining nearly one-third of the trade during the war, now retains only 13 per cent, while salt from Italian East Africa which made its appearance about the same time, now makes up 16 per cent of the total. Spain still supplies India with 7 per cent of her requirements, the same amount as in 1904-08, when the trade first started. Practically no salt is made in Bengal, and 85 to 90 per cent of the imports come to Calcutta, the remainder going chiefly to Burma (see Table XXXI).

Of the home production, the Bombay and Madras Presidencies between them yield two-thirds of the salt, and Northern India 30 per cent. For the past thirty years, the proportions have been much the same, though Bombay, including Sind, has decreased slightly and Northern India increased by much the same amount. The Burmese production has fallen from 2·2 to 1·6 per cent of the total over the same period of time.

Indian salt is derived from three sources—the sea, subsoil brines and the waters of lakes of enclosed drainage, and from beds of rock salt.

*Sea Salt.* Most of the salt manufactured in Bombay, Madras and Burma comes from sea water. In the Bombay Presidency the salt factories at Dharasna and Chharvada, on the east of the Gulf of Cambay, are the property of the Government, and are worked departmentally. The other sea salt works, with three exceptions, are grouped within a radius of 30 miles of Bombay itself, those which are Government property being leased to operators, while the others are owned as well as worked privately. The Okha Salt Works Ltd. have recently commenced the manufacture of fine white crushed salt, for the Calcutta market, near Port Okha in Kathiawar. The process followed depends entirely on solar evaporation, the reservoirs

and crystallizing pans, protected by embankments, lying below the level of high spring tides. The manufacturing season varies with the south-west monsoon, but lasts normally from January to June. Much of the salt made in the Bombay Presidency comes from the brine of wells on the Little Rann of Cutch, and there are works at Kharagoda and Udu, owned by the Government and worked departmentally, in addition to those at Khuda, operated by the Dhrangadhra State. Here, too, the heat of the sun is relied upon after the brine has been raised from the shallow wells. The season lasts from November to April. A large amount of salt is also made in Sind at the Maurypur works, near Karachi. With a mean annual rainfall of 7.64 inches, normally distributed over 9 days, a dry atmosphere which is seldom still, and a mean daily maximum temperature of 84° F., conditions for rapid solar evaporation are practically ideal, and it is not surprising that manufacture is carried on for nearly 11 months of the year.

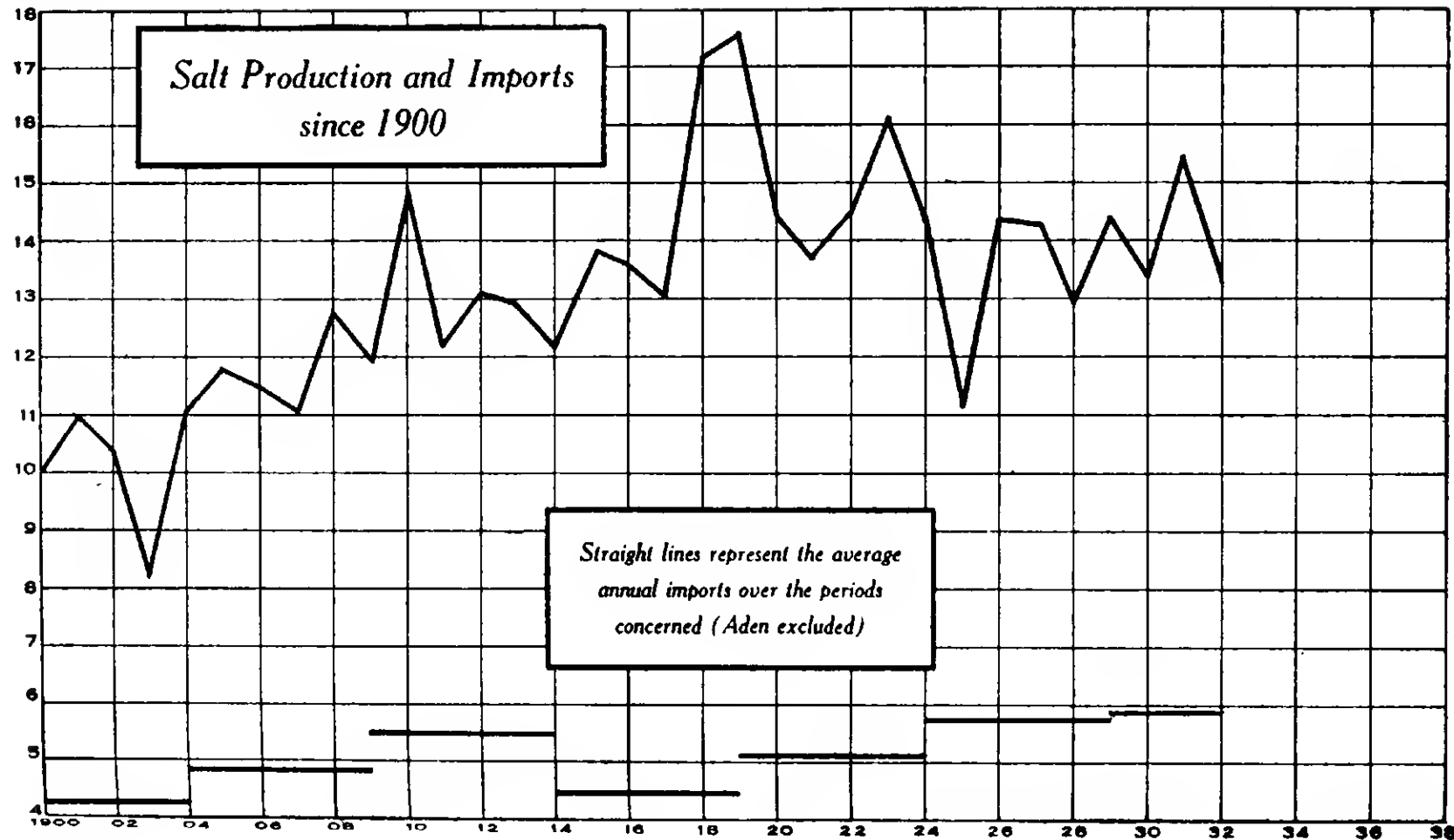
The salt-producing districts of the Madras Presidency are classified by Swaminathan into three groups: a northern one extending from Ganjam to the Kistna district, a central group reaching from the latter to Chingleput, while the southernmost stretches from Chingleput down the east and up the west coast as far as the Udipi district in Malabar. In 1930, there were approximately 48 centres in these three groups, with 68 factories scattered along 1,600 miles of coast. The season varies from January or February to June or July in the north, while further south it commences later, in March or April, and continues until August or September. In the extreme south, as, for example, in Tuticorin, salt is harvested up to October or even November. Evaporation depends entirely upon solar heat.

Many of the coastal districts of Burma and particularly those of southern Tenasserim—Amherst and Tavoy—yield salt from sea water, but the method followed differs from the Indian practice, the brine being concentrated in the open air by solar evaporation until its calcium sulphate has precipitated, when the concentrated liquor is boiled almost to dryness in shallow iron pans heated by wood fires. By this means a fine white salt is produced which is more acceptable to the local market than the cruder, more coarsely crystalline Indian product. In many districts of Upper Burma, salt is made on a small scale from well brines or by the lixiviation of saline earths.

*Lake Salt.* Salt is also made from subsoil and lake brines; Sambhar,



HUNDRED  
THOUSAND  
TONS



Graph 10



EXTRACTION OF SALT FROM LAKE SAMBHAR, RAJPUTANA

the largest of the salt lakes of Rajputana, alone contributing about a quarter of a million tons per annum. Covering an area of some 90 square miles at its highest level, it dwindles to a small central puddle by March or April. W. A. K. Christie has proved that the muddy bottom down to a depth of 12 feet contains at least 50 million tons of salt. Plate VII, a photograph by W. A. K. Christie, reproduced by permission of the Director, Geological Survey of India, shows the extraction of salt from the Sambhar lake. Brine brought to the surface by capillarity evaporates and forms each year a layer of salt which is dissolved by the monsoon rains. The researches of Sir Thomas Holland and Christie have proved that most of the salt in this part of India is brought in as fine dust from the Rann of Cutch by the prevailing air currents of the hot season. Each following monsoon supplies sufficient rain water to carry a load of it in solution into the lakes and valleys of enclosed drainage. Subsoil brine is utilized at Pachbhadra in Rajputana and at other places.

**Rock Salt.** About 12 per cent of the Indian production is represented by rock salt, and 85 per cent of this comes from the mines of the Punjab Salt range, the remainder from Kohat in the North-West Frontier Province and from Mandi State in the Punjab Himalaya. Abul Fazl, in the *Ain-i-Akbari*, mentions the salt diggings of the Punjab Salt range and the use of the mineral for 'dishes, plates and covers and stands for lamps', as well as its more usual purposes. Mining was extensively carried on under the Sikh rule, but it was many years after the occupation of the Punjab (1849), that the geological relationships of the deposits were studied and a systematic mining plan laid out by Warth in 1872. In the Mayo mines at Khewra, Jhelum district, there are four seams, known as the Buggy, Sujawal and Upper and Lower Pharwala seams; the maximum thickness of the first is at least 150 feet, of the second about 50 feet, of the third 70 to 80 feet and of the fourth 120 feet. E. R. Gee estimated in 1930 that a minimum reserve of about four million tons still exists in this mine. There are other mines and quarries at Varcha, Shahpur district; Kalabagh, Mianwali district and elsewhere. Prospecting in the Jansukh valley near Varcha has recently revealed the existence of a very thick seam of workable salt.

The rock salt of the Kohat district occurs in beds of great thickness, exposed along the axes of a series of narrow folds. At Bahadur Khel the salt beds extend over 4 miles, with a breadth of a quarter to

**TABLE XXX**  
**AVERAGE ANNUAL PRODUCTION AND IMPORTATION OF SALT IN INDIA**

PERIOD		PRODUCTION	IMPORTS	TOTAL	PROVINCIAL SHARES OF PRODUCTION				ROCK SALT
					Bombay and Sind	Madras	Northern India	Burma	
1898-1903	...	<i>Tons</i> 979,572	<i>Tons</i> 433,754	<i>Tons</i> 1,413,326	% 37·6	% 30·4	% 29·7	% 2·2	% 11·2
1904-08	...	1,167,785	484,940	1,652,725	36·9	33·3	27·4	2·2	10·3
1909-13	...	1,301,901	552,299	1,854,200	37·0	31·0	29·0	2·1	11·5
1914-18	...	1,395,102	443,575	1,838,677	34·9	30·3	31·2	2·8	12·7
1919-23	...	1,530,272	517,894	2,048,166	35·0	31·4	30·2	3·2	11·6
1924-28	...	1,343,587	580,943	1,924,530	34·0	33·0	31·3	1·6	12·1
1929-32	...	1,418,185	594,281	2,012,466	33·8	31·1	33·4	1·6	12·1

Salt production for the two years ending 1934 averaged 1,516,277 tons per annum.

**TABLE XXXI**  
**SOURCES OF INDIAN SALT IMPORTS**

PERIOD	AVERAGE ANNUAL TOTAL	SHARES OF VARIOUS COUNTRIES								
		United Kingdom	Germany	Aden	Arabia	Egypt	Spain	Italian East Africa	IMPORTED INTO	
									Calcutta	Rangoon
1898-1903	... <i>Tons</i> 433,754	% 56·1	% 13·1	% 11·4	% 9·9	% 6·5	% ...	% ...	% 89·8	% 10·1
1904-08	... 484,940	45·2	14·0	14·4	12·4	5·6	7·4	...	88·8	11
1909-13	... 552,299	29·8	10·3	16·7	11·8	10·3	16·6	4·3	90	10 <sup>1</sup>
1914-18	... 443,575	17·6	1·4	25·6	1·4	30·3	13·5	10·2	90	10 <sup>1</sup>
1919-23	... 517,894	17·1	8·5	31·1	...	21·5	10·6	11·0	88	12 <sup>1</sup>
1924-28	... 580,943	14·2	8·2	33·4	...	22·4	9·0	9·3	85	15 <sup>1</sup>
1929-32	... 594,281	7·7	10·5	42·0	...	12·9	7·6	16·3		

Imports of salt for the two years ending 1934 averaged 379,490 tons per annum.

<sup>1</sup> Approximate percentage.

half a mile. The visible thickness of salt exposed is at least 1,000 feet, according to Wynne and Warth, while two hills, about 200 feet in height, are entirely composed of salt. The mineral is won by quarrying, and the resources of the region are practically inexhaustible. From the Jutta quarries alone an annual output of nearly 15,000 tons is obtained, while a reserve is available which E. R. Gee, in 1933, thought would probably last at this rate for fifty years.

The rock salt deposits of Mandi State were described by Medlicott in 1860 and occur in a zone of limestones, shales and sandstones, perhaps of Tertiary age, close to their faulted junction with older rocks.

### OTHER SODIUM COMPOUNDS

Many tracts in the Indo-Gangetic plain lying chiefly in a well-defined meteorological region which includes the Punjab, Sind, Rajputana, the upper portion of the United Provinces and the north-western districts of Bihar, characterized by scanty rainfall, low humidity and excessive heat, are worthless for cultivation owing to alkaline efflorescences from the soil, which vary in composition from place to place, but usually contain the sulphate, carbonate and chloride of sodium. Such areas are not entirely confined to Upper India: H. F. Blanford and W. King described barren, soda-bearing soils of widespread occurrence in the South Arcot and Trichinopoly districts of Madras, while in certain parts of Mysore, particularly in the Tumkur and Chitaldroog districts, hundreds of acres are covered with these deleterious substances between December and March, causing either lowered fertility or complete abandonment of the land. They also prevail in portions of the dry zone of Upper Burma.

The salts usually originate from accumulations of the soluble products of rock decay in the subsoil water of regions of poor drainage, which are brought to the surface by capillary action in the dry season and left as solid deposits on the evaporation of the water containing them.

These efflorescences are known as *reh* in the United Provinces, as *kalar* further west, while the crude mixtures of sodium salts prepared from them are called *saji matti* in Upper India, *chowhi chakke* in Mysore and *sapaya* in Burma. In days previous to the large scale importation of sodium salts from abroad, there was a thriving industry in the extraction of such products by simple

processes of lixiviation and solar evaporation, and they were used in the manufacture of crude glass and soap, for curing hides and skins, and in tanning leather. Today these alkaline earths can still be purchased in the bazaars and they are hawked about the residential quarters of the towns, where they are used by dhohis for laundering and by the poorer classes for the cleansing of cooking utensils and domestic purposes generally.

Crude soap is still manufactured, according to Mr P. K. Ghose (1934), from alkaline incrustations gathered near the banks of the Bokh and Khari rivers, near Parantij, Ahmadabad district, Bombay. It is said to yield an annual income of about two lakhs of rupees to the makers.

According to information supplied to the Geological Survey of India by Imperial Chemical Industries Ltd., a specimen of *saji matti* on sale in Calcutta contained 27 per cent of sodium carbonate, 4.28 per cent of sodium bicarbonate, and nearly 34 per cent of sodium sulphate. Another variety from Dehra Dun carried 31.44 per cent of sodium carbonate and nearly 7 per cent of the bicarbonate. Common salt and sodium sulphate appear to be the original ingredients, the carbonates being formed when lime is present in the soil, while nitrates are produced if organic nitrogenous matter is available (see SALTPETRE).

There are no available statistics relating to the production of *saji matti*, but it is still gathered on a fairly extensive scale in many parts of the United Provinces. Benares, Azamgarh, Jaunpur and Ghazipur are stated to send 2,000 tons annually to Calcutta alone, and it is also collected around Cawnpore, Hathras, Muttra, Shahjahanpur and Dehra Dun. The Wundwin township of the Meiktila district is one of the most important producing regions of Burma, and the annual out-turn of the whole province ranged between 3,590 and 8,500 tons a decade ago.

Many proposals have been made, and experiments conducted, to extract and utilize the sodium salts from the alkaline earths on a commercial scale, but only one can be referred to here. From 160 tons of earth collected in the Nejanti and Tadaklur areas, Tumkur district, Mysore, in 1919, A. M. Sen obtained 13 tons of crude soda averaging 29 per cent of sodium carbonate and 8 per cent of sodium chloride, which was sold to the Bangalore Woollen, Cotton and Silk Mills Co. Ltd.

Crude sulphate of soda (*khari*) is made in the three north-western

districts of Bihar—Muzaffarpur, Saran and Champaran—which are also saltpetre-producing areas. During the 14 years, 1908–09 to 1922–23 (no figures being available for 1918–19), the total out-turn was 207,851 tons, valued at Rs. 4,934,182, of which the three districts in the order named were responsible for 62, 27 and 11 per cent respectively. In 1923–24 and 1924–25, a further total of 20,778 tons was recorded, but after that date the collection of the returns was suspended, owing to the withdrawal of certain restrictions on the manufacture of saline substances. The chief use of *khari* is for preserving hides and as a veterinary medicine. There are said to be extensive soda efflorescences in southern Bihar, particularly south of Nawada, in the Gaya district, and in Sheikpura (Monghyr). Sodium sulphate occurs in the brine of the Sambhar salt lake, Rajputana, the amount present, according to analyses by Sir Thomas Holland, averaging 3 cwt. 1 qr. per ton of the total salts.

Sodium carbonate has been obtained for centuries from the water of the shallow Lonar lake on the southern border of the Buldana district of Berar, which was first described by J. E. Alexander in 1824, and from the alkaline mud which covers the hollow in which it lies, as the waters recede by evaporation in the hot season. G. Smith, writing in 1850, stated that operations had not been carried on regularly since 1836, when the output was about 460 tons of soda annually; and in later years, like so many other indigenous industries, it has been unable to compete successfully against cheaper imported substances. Over the years 1909–13, a total of 446 tons valued at Rs. 16,719 was produced, followed by a blank period lasting nine years. A revival occurred in 1923 with an output of 600 tons, worth Rs. 23,750, which, however, was not sustained as the following three years, 1924–26, only yielded a total of 155 tons. Working was in abeyance between 1927 and 1929, and the out-turn of 100 tons in 1930 is the last recorded production. As the water of the lake, which had an area of 94 acres in March 1910, evaporates, various crops of crystals, known under different vernacular names, are formed on the bottom. They vary in composition, but the relative proportions of sodium carbonate and bicarbonate are similar in all of them and seem to consist of the definite compound  $\text{urao}$  ( $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$ ) mixed with varying quantities of sodium chloride and other impurities. W. A. K. Christie estimated that the total amount of sodium carbonate in the brine was about 2,000 metric tons, while the



upper  $1\frac{1}{2}$  metres of the mud around it contained a further 4,500 tons. He believed that the sodium is derived from the basaltic rocks of the neighbourhood, which contain 1.74 per cent sodium, while an unlimited supply of carbonic acid is available in the atmosphere and in percolating waters which leach out the alkalis from the parent rocks as carbonates or bicarbonates. A few tons of soda are produced in Ladakh annually, presumably from the waters of alkaline springs which are known to exist in that region, the output varying from 7 to 28 tons per annum over the past decade.

The soda industry of Sind was investigated by G. de P. Cotter in 1918-19, who states that it has existed from time immemorial. On a Survey of India map published between 1860 and 1863, one of the lakes concerned is marked 'natron producing'. The *dhands* of the Sind desert are shallow lakes occupying suitable sites which have not been covered by the surrounding sand-hills. Water percolating into them from the basal layers of the surrounding dunes carries the salts in solution, which yield a thick crust of *chaniho* after the periodical dessication of the dry season. Analyses of *chaniho* vary a great deal, and in this respect resemble *reh*. A list of a large number shows the sodium carbonate ranging between 33 and 47 per cent, the bicarbonate between 21 and 23 per cent, the chloride usually under 5 per cent, and the sulphate from under 1 to 5 per cent. Specimens from some *dhands* however, may contain from 30 to 50 per cent of the sulphate and in extreme cases even more. Cotter believes that the conversion of the sulphates in the waters into carbonates is a result of bacterial action, brought about before the salts reach the lakes themselves—a modification of a theory advanced by E. Sickenburger, in the case of the alkaline lakes of Egypt. Some of the bigger *dhands* contain large quantities of soda: the two largest, Pur Chanda and Khariri, probably contain up to 25,000 tons each.

The *dhands* are divided into two groups—(1) the Nara group, located in a belt of country, 10 to 12 miles wide, bisected by the Nara river and extending from the south of Khairpur State into the Nawabshah and Thar and Parkar districts, and (2) a group east of Kot Jubo, in the eastern part of Khairpur and close to the borders of Jaisalmer. The Thar and Parkar district has not yielded *chaniho* since 1899, the *dhands* having become dry as a result of canalization. Counting both groups of the Khairpur State, Cotter found 30 producing, and 40 dry *dhands*, as well as 30 which in that particular

season happened to contain excessive water. In addition to these, there are many more which have never yielded sodium salts by the methods practised locally. In the Nawabshah taluk, the corresponding figures were 3 producing, 20 dry, and 4 *dhands* with excessive water. The annual production of crude sodium carbonate from Sind tends to be erratic, and as the figures given in the table below show, has averaged from under 1,000 to more than 4,000 tons per annum during the period for which statistics are available.

The local demand for the mineral is not large, though it is used to a certain extent in cooking, for converting sugar-cane juices into molasses and for washing clothes, but the bulk of the production reaches Karachi for export. For the three years ending 1928-29, the average annual exports thence were valued at Rs. 1,61,454 and were almost equally divided between the coastal trade, mainly to ports in Bombay, Kathiawar and Madras, and the foreign trade, of which Aden and its dependencies took 78 per cent, Muscat, Oman and other Arabian States accounted for a further 12·5 per cent, leaving the remaining 9·5 per cent to be divided between Ceylon, Persia and East African ports.

**TABLE XXXII**  
**PRODUCTION OF CHANIHO IN SIND**  
*Average annual figures in tons*

PERIOD	KHAIRPUR	NAWABSHAH	TOTAL
1895-96 to 1899-1900 ...	2,089	<sup>1</sup>	2,089
1900-01 to 1911-12 ...	<sup>1</sup>	<sup>1</sup>	
1912-13 to 1916-17 ...	734	252 <sup>2</sup>	986
1917-18 to 1921-22 ...	3,832	287 <sup>3</sup>	4,119
1922-23 to 1926-27 ...	2,387	185	2,572
1927-28 to 1928-29 ...	737	148 <sup>4</sup>	885

The importation of sodium compounds of foreign origin into India continues to increase; in 1905 they had an estimated value of £70,000; in 1913 of £212,649; in 1918 of £651,885; from 1919-23 they averaged £656,553. The average annual quantities and values of the various salts imported over the period ending 1932-33 are

<sup>1</sup> No figures available.      <sup>2</sup> Two years ending 1916-17 only.

<sup>3</sup> Average of four years only.      <sup>4</sup> One year, 1927-28 only.

given in Table XXXIII for comparison. The figures in brackets are the corresponding quantities for the five years ending 1928.

TABLE XXXIII

IMPORTS OF SODIUM COMPOUNDS INTO INDIA  
FROM 1928-29 TO 1932-33

*Average annual figures*

		<i>Tons</i>	<i>Rs.</i>
Sodium Carbonate (Soda Ash and Soda Crystals) ...	54,509	(47,607)	64,91,569
Sodium Bicarbonate ...	5,267	( 5,404)	8,10,257
Caustic Soda ...	11,411	( 7,437)	26,73,189
Sodium Sulphide ...	2,045		2,92,206
„ Sulphate ...	75 <sup>1</sup>		9,005
„ Silicate ...	1,794		2,84,350
„ Bichromate ...	623		2,93,590
„ Diborate ...	1,076		2,44,562
„ Cyanide ...	422		4,27,979
Other Kinds ..	1,260		4,75,879
TOTAL ...	78,482		1,20,02,586*

Two attempts have been made to manufacture sodium compounds on a large scale by modern methods in India. The Magadi Soda Co. erected a plant at Budge Budge, near Calcutta, for the production of caustic soda from the natural carbonate imported from Kenya, but went into liquidation about 1925. The Shri Shakti Alkali Works at Dhrangadhra, the property of the State of the same name in Kathiawar, were, according to information kindly supplied by the Minerals Adviser to the High Commissioner for India, started about 1928, but up to 1934 had only worked twice for about 18 months. The works were designed to produce 60 tons of soda ash per day, but it is understood that not more than 25 to 30 tons daily were made during the operating periods. The quality of the product was considered satisfactory. The factory is at present being remodelled and reorganized, and it is hoped that it will eventually provide a reliable source of good soda ash at competitive prices.

In May 1935, Imperial Chemical Industries Ltd. announced the progress of investigations for the manufacture of alkali in India. Should this prove justified a new Company is to be formed in which Indian capital will be invited to participate.

<sup>1</sup> Separately recorded from 1932-33.

\* £900,000 approximately.

## BORAX

There are several natural borates of commercial importance occurring generally as saline residues in dried-up lake beds and marshes, whence they are supposed to have been derived from hot springs of volcanic origin. Borax, sodium diborate, is the only one of any importance as far as India is concerned, and it arrives on the market from Tibet in the form of large transparent prisms, often dulled on the surface. It is known as *sohaga* or *tincal*.

The region from which it comes stretches from the Puga valley of Rupshu, in Eastern Kashmir, into Hundes, in south-western Tibet. In the Puga valley, at an elevation of 15,000 feet, there are numerous hot springs draining into a stream, on the banks of which borax occurs in thin layers, associated with salt and sulphur. Between Rudok, Thok Jalung and Lake Manasarowar in Tibet, the existence of several borax fields has been indicated by travellers. In the borax-producing region of Hundes, the mineral is obtained with common salt, by lixiviating the soil from the borders of dessicated lakes. These circumstances suggest the existence of exhausted and slowly declining solfataric conditions, connected with a phase of comparatively recent volcanic activity.

The earliest mention of the existence of borax in these trans-Himalayan regions by a European writer was made in 1563, and three communications regarding them were made to the Royal Society in 1786, 1787 and 1789. Statistics of the imports and sales date back to 1813, and in 1854 Marcadieu was deputed to examine the Puga deposits on behalf of a syndicate of English pottery manufacturers. The high-water mark of the trade was reached about 1885, when the imports into India across the frontier totalled about 1,600 tons, of which over 1,000 tons were exported, chiefly to the United Kingdom. The export trade to Europe was killed soon after this by the discovery of natural borates in America and elsewhere, though India continued to send the Tibetan mineral to the Straits Settlements and Hong-Kong. Transported over the Himalayan passes on the backs of goats and sheep, the crude borax reached the plains of the United Provinces to be refined at Ramnagar and elsewhere. The much smaller quantities from Ladakh reached Jagadhri, the entrepôt of the Punjab trade.

From the beginning of the present century onwards until the old system of registration of trans-frontier trade was discontinued in

1925, and figures for the imports of borax became no longer available, the trade was remarkably steady, averaging a little over 1,000 tons per annum, 95 per cent of which came from Tibet and the remainder from Ladakh and Central Asia, worth at the close about Rs. 496 per ton. The exports by sea have, however, dwindled to 105 tons per annum as the average for the period 1924-28, and to 61 tons, valued at Rs. 24,308, the average for the five years ending 1933, the bulk of the material being shipped, via Calcutta, to the Straits Settlements and Hong-Kong. At the same time the annual imports of boric acid and borax from foreign countries into India have increased up to a maximum of 1,642 tons valued at Rs. 3,25,483 in 1931-32, and for the five fiscal years ending 1933 averaged 1,076 tons, valued at Rs. 2,44,562. In the first edition of this book the following statement was made: 'The extreme isolation of the borax lakes, the political conditions which render their examination impossible, and the almost insuperable difficulties of transportation over the highest mountains in the world, all combine to retard development: that the Tibetan borax will continue to be able to hold its own against imports from abroad is the utmost that can be hoped for.' The regrettable absence of the trade statistics from 1925 makes it impossible to investigate the existing position, but the fact that exports of borax by sea still figure in the returns, though in diminishing quantities, would seem to prove that the trade continues to some extent.

Borax finds varied uses in industrial and domestic life. It is a valued flux in many chemical and metallurgical operations. It is employed in the brazing, soldering and welding of metals and in the manufacture of enamels and porcelain-like surfaces for domestic metal ware. It is used as a glaze in laundry work and in the preparation of fine stationery. The glass industry takes its regular quota, and the tanneries and glue factories are regular consumers. The textile trade uses it as a solvent-bleach, mordant and fireproofing. The soap-maker and the cosmetic manufacturer find it indispensable. It also finds an outlet in the oil and paint trades. The antiseptic properties of borax and boric acid are known to everyone, and their uses in medicine and surgery and as food preservatives need only be mentioned. Finally, boron and its compounds are employed as scouring agents in casting copper, nickel, aluminium and their bronzes.

## MAGNESIUM CHLORIDE

Magnesium chloride and its sulphate occur with sodium chloride and other salts in sea water, and in the manufacture of common salt from this source they become concentrated in the 'bitterns', the residual mother liquors left after the salt has crystallized out.

Magnesium chloride is used on a large scale in the textile industry, for by reason of its hygroscopic character, mixed with other ingredients of the size, it helps to keep the yarn pliable and soft, to increase its strength and weight, and to enhance its appearance. Other common ingredients of textile sizes are organic substances such as flour, tallow and starch, and minerals, or chemicals, like china clay, zinc chloride and magnesium sulphate (Epsom salts). During the four years ending 1928, the average annual imports of magnesium chloride, classified as such, were about 3,000 tons, the greater part of which reached Bombay. The local production at that time averaged about 2,000 tons per annum, and the requirements of the Bombay cotton mills alone are probably about 4,500 tons per annum. The successful production of this compound on a commercial scale in India is due to the enterprise of Mr B. S. Lalkaka of the Pioneer Magnesia Works which, commencing with an output of 966 tons in 1916, had reached some 3,000 tons in 1928, later figures not being available. Between 1916 and June 1928, according to evidence given before the Indian Tariff Board, 16,892 tons, valued at Rs. 23,73,061, had been marketed. Two plants are in operation, one at Kharagoda, near Viramgam, on the Rann of Cutch, about 350 miles from Bombay and 50 miles from Ahmadabad; and the other on the coast at Mithapur, 7 miles from Port Okha in Kathiawar. The former, on the outskirts of the Pritchard Salt Works, uses the waste liquors originally derived from brine wells and produces mainly for the domestic mill market. The latter, operated in conjunction with the Okha Salt Works, supplies the export trade, the process of manufacture being rather more difficult here, as the original brines come directly from the sea. The industry has made great strides in recent years, with the result that besides meeting almost the whole of the needs of the local textile industry, Indian magnesium chloride is finding its way into the world's markets in increasing quantities, in spite of keen competition from German sources which have hitherto enjoyed a monopoly of the business. In 1933, a few thousand tons were shipped to the United Kingdom, Holland, Scandinavia, Austria and other European countries as well as

to South Africa and Australia. Magnesium sulphate, Glauber salt and bromides can also be obtained from sea brines, and it is hoped to manufacture these products in the future at the Pioneer Magnesia Works.

In addition to its applications in the textile industry, magnesium chloride is used with magnesia to prepare the oxychloride, or Sorel cements, which have many applications in building construction, the formation of jointless floorings, artificial stone, stucco, etc. The solutions of the salt form a valued refrigerating medium, which possesses the advantages of being more viscous and of freezing at lower temperatures than brines of the same concentration. It is also used for fire-proofing wood, in the treatment of mine timbers, in fire extinguishers and in preparations for laying dust on roads, in addition to many other minor purposes.

With the exception of a paper published by Mr Lalkaka in 1922, in which the methods of manufacture followed in India are described, little has been written on this subject; the later details given here have been supplied by the courtesy of the Pioneer Magnesia Company.

**TABLE XXXIV**  
**IMPORTS OF MAGNESIUM COMPOUNDS**  
**1928-29 TO 1932-33**  
*Average annual figures*

	<i>Tons</i>	<i>Rs.</i>
Magnesium Chloride ...	1,545	1,08,724
Magnesium Sulphate ...	1,708	1,22,599
Others ... ..	120	22,306

## BAUXITE

In the year 1883, F. R. Mallet discovered that a variety of laterite from the Jubbulpore district, Central Provinces, contained a large proportion of aluminium. In 1903, Sir Thomas Holland anticipated that some of the laterites which cover so large a part of the surface of the Peninsula would prove to be related to bauxite, a hydrated oxide of aluminium and the principal ore of that metal. Later in the same year, H. and F. J. Warth actually proved that many of the Indian laterites are indeed bauxite, and field investigations led to the publication in 1905 of 17 analyses of bauxite from various parts of Bengal, Bombay, Madras, Central India and the Central

Provinces. In 1923, C. S. Fox's exhaustive account of the bauxite and aluminous laterite occurrences appeared. This brief note is partly drawn from that source and to it the reader is referred for further details.

Laterite is a residual product of rock decay in tropical climates, subjected to alternating wet and dry seasons, and in chemical composition it is essentially a mixture of ferric hydroxide, aluminium hydroxide and free silica in varying proportions; in addition to these it frequently contains titania. Between bauxite and laterite there is no sharp dividing line, for the one may pass gradually into the other. The greater proportion of the larger spreads of laterite are far too ferruginous to be of any use as ores of aluminium, and such material has indeed been utilized in the past as iron ore. Bauxite itself may be regarded as a mixture of two hydroxides of aluminium, (diaspore, aluminium oxide combined with one molecule of water, and gibbsite, the same with three molecules of water). Almost all the aluminous laterites or bauxites are of a primary nature. They have been formed in the places they now occupy. In addition, all the better known bauxite occurrences of the Peninsula are connected with the decomposition of the basaltic flows of the Deccan.

The richer bauxite areas are situated on the Baihar uplands of the Balaghat district and in the neighbourhood of Katni, Jubbulpore district, Central Provinces; in the States of Sirguja and Jashpur, and in the districts of Mandla and Bilaspur, Central Provinces. More definite areas which have been carefully examined and in which good bauxite is known to occur include the following: Chakar in Jammu, Kashmir, where the quantity available in a surface layer, 4 feet thick, is officially stated to be over 1,800,000 tons; Rupjar, Balaghat district, Central Provinces, where the deposits consist of boulders of aluminous laterite in soft ferruginous soil; Radhanagri, Kolhapur State, Bombay, where an elongated plateau of basalt lavas is capped with highly aluminous laterite, on the north-western spur of which quantities of bauxite of the order of two million tons are available; and Pakripat in the Ranchi district of Bihar.

The following 'Hints for searching for Bauxite' have been given by Fox. The family name of the whole set of rocks is laterite. When the percentage of iron is more than 40 per cent it is a ferruginous laterite. When the percentage of alumina is over 40 per cent, the specimen would be called an aluminous laterite or bauxite. The tops of laterite-capped, flat hills of trap (lava) should



be examined. These flat hills are usually the highest land in the trap areas. The best places to search are the scarps and particularly the uppermost ten feet of them. It is common to find that the very top of a scarp is made of the iron variety of laterite, but just under this ferruginous mantle the best grey bauxite occurs at depths of from 1 to 5 feet. If the plateau is extensive, rich bauxite frequently occurs at the commencement of the stream courses which drain it, either in the stream bed itself or close along its margins, as a kind of rough pavement. Here, too, there may be a slight development of the red ferruginous covering. Another guide to the location of bauxite deposits is the occurrence of a cream-coloured clay on the hillside below the laterite scarps.

Quarrying operations for bauxite in India started in the Katni area of the Jubbulpore district, Central Provinces, in 1908, and in the Khaira district of Gujerat, in 1920. The total output up to the end of 1930 was a little more than 100,000 tons and of this some 68,000 tons came from the Khaira district, 31,000 tons from the Jubbulpore district, and the remainder from prospecting work in Belgaum district the Savantvadi State of Bombay. Between 1931 and 1934, inclusive, 9,858 tons were produced, almost entirely from the Jubbulpore district. The average declared 'pit's mouth' value over a period of five years ending 1934 was Rs. 3-5-0 per ton, though this is little guide to the actual value of any particular variety and may merely represent the approximate cost of extraction.

About two-thirds of the world's annual production of bauxite, which now reaches in normal years over 2,000,000 tons and is won mainly in France, the United States of America, British and Dutch Guiana, Yugo-Slavia, Hungary and Italy, is absorbed in the manufacture of metallic aluminium. The possibilities of making this metal in India have been discussed for thirty years, but for various reasons no project has advanced beyond that stage. The growth of successful aluminium enterprises in other countries has depended more on the provision of abundant and sufficiently cheap electrical energy and on large-scale production than on any other factors. Factories exist at which imported aluminium is made up into a variety of domestic utensils, etc., and are situated at Madras, Calcutta, Bombay, Rangoon, Benares, Gujranwala and Amritsar.

The remainder of the world's bauxite output is utilized for the following purposes:

1. Manufacture of chemicals and notably of alum and the aluminous sulphates, which are extensively employed in water purification, dyeing, tanning, etc. There is a steady demand in India from chemical manufacturers for small amounts of bauxite, containing less than 3 per cent of ferric oxide, for the preparation of alum, alum cake and aluminio-ferric.

2. Manufacture of artificial abrasives. These are made in the electric furnace, notably at the Niagara Falls, by fusing calcined bauxite. They are artificial forms of corundum and emery and are marketed in very large quantities under various trade names.

3. Manufacture of refractories. Bauxite bricks, prepared from the calcined mineral in kilns, and other products made by fusing it in the electric furnace and casting the molten material, are increasingly used for lining various types of furnaces, cement kilns, etc.

4. Petroleum purification. Bauxite filters are installed in oil refineries for the purification and decolorization of kerosene. The Indian material from the Khaira district is largely used for this purpose.

In existing world conditions, the expansion of the Indian bauxite industry depends on the further utilization of the mineral for these so-called minor purposes.

## ALUM AND RELATED SUBSTANCES

At one time India's requirements of alum were met from internal sources by the treatment of alum shales. These are thinly bedded, easily fissile rocks containing varying quantities of small, sometimes microscopic, and well disseminated crystals and grains of iron pyrites. When exposed to the action of the air, the pyrite oxidizes, and the acid solutions so generated react upon the aluminous compounds present and form sulphates of aluminium. In actual practice the methods of treatment adopted varied somewhat in different parts of the country, the shale after mining being either exposed to atmospheric agencies for some months, or piled into heaps with alternate layers of brushwood, and fired for lengthy periods. In the second part of the process, the burnt or oxidized shale was lixiviated in vats or tanks with water, the liquors drawn off, concentrated, and then treated with saltpetre, wood ashes, or more commonly with solutions of *reh*, the alkaline efflorescence scraped from the surface of the soil in dry parts

of the country. The latter yielded an impure product in which the soda alum predominated, while from the former a purer form of potash alum was produced. There used to be extensive works carrying on these operations in the Shahabad district of Bihar and Orissa, which obtained their supplies of pyritous shales from the Kaimur sandstone series of Vindhyan age; at Mhurr, in Cutch, where the raw material was a soft breccia from the sub-Nummulitic group; at Khetri and Singhana in Jaipur State, Rajputana, using shales of Aravalli age from the local copper mines; at several places in Sind; and at Kalabagh and Kotki in the Mianwali district of the Punjab. A detailed account of the manner in which alum was manufactured at the last-named places was given by N. D. Daru in 1910. The raw material used was an alum shale, taken from the base of the local Eocene rocks, with an extremely finely divided pyrite content averaging 9.5 per cent sulphur. The product was mainly soda alum, which was disposed of in Delhi, Hissar, Sirsa and other centres of the tanning and dyeing industries.

The indigenous processes of manufacture resembled those discarded in Europe long ago in favour of more economical ones using china clay or bauxite as a starting-point, and the Indian industry has slowly languished before the competition of imported alum and aluminous sulphates, and of such chemicals now produced in India itself by the more modern methods. The trend of this decline can be seen from the following table:

TABLE XXXV

## ALUM AND THE ALUMINOUS SULPHATES

*Average annual figures*

PERIOD	IMPORTS		PRODUCTION (Mianwali only)	
	Tons	Rs.	Tons	Rs.
1897-98 to 1902-03 ...	3,465	2,98,725	Records incomplete	
1903-04 to 1907-08 ...	3,385	3,03,965	284	30,705 (1904-08)
1908-09 to 1913-14 ...	3,812	3,52,710	302	42,180 (1909-13)
1914-15 to 1918-19 ...	5,828	9,52,485	318	59,715 (1914-19)
1919 to 1923 ...	6,429	12,66,270	180	69,966
1924 to 1928 ...	6,086	6,89,322	65	24,166
1929 to 1933 ...	4,993	4,37,563		

Since 1928, no alum has been manufactured in the Mianwali district and the industry appears to have succumbed. The reason is

apparent from the figures quoted over the decade ending 1928, for while the annual imports have remained more or less stationary, the value has declined by half. Pyritous shales which could be used for the manufacture of alum are known to occur in other places in addition to those mentioned, but it is hopeless to expect a revival by means of the time-honoured practices, though there might be more extended manufacture of aluminium salts from Indian bauxite in the country if cheap and abundant supplies of indigenous sulphuric acid were available. It is difficult to gauge the extent to which such chemicals are now made in India. The Tariff Board in its report on the Heavy Chemical Industry, published in 1929, estimated the local production of aluminium sulphate and alum as 410 tons in the Bombay Presidency and 1,650 tons in Bengal. C. S. Fox, however, in a statement published in 1930, gives the out-turn of one Calcutta firm alone as 1,800 tons in addition to 600 tons of alum cake.

By the treatment of bauxite with sulphuric acid, the crude product known as alum cake is obtained. If this is dissolved in water and the insoluble impurities removed, the solution then being concentrated and allowed to solidify, 'alumino-ferric' is produced. This product, which, as its name indicates, still contains much iron, is used on a large scale in paper-making, sewerage treatment and water clarification. The purer varieties of aluminium sulphate are prepared by dissolving the artificially made hydroxide in sulphuric acid; while for making potash alum, the double sulphate of aluminium and potassium, potassium sulphate is required as well as bauxite and sulphuric acid. In addition to their uses in the curing and tanning of skins and in dyeing, these salts are employed in printing, colour making and in the manufacture of fireproofing materials.

### STEATITE

Steatite or soapstone is the compact, often impure, structureless variety of talc, a silicate of magnesium,  $[\text{H}_2\text{Mg}_3(\text{SiO}_3)_4]$ , which normally has a mica-like cleavage, a characteristic soapy feel, and is often foliated. Talc schists are widely distributed amongst the crystalline rocks of India, and some varieties form the potstones which have been quarried for centuries to be carved into Hindu culinary utensils, especially in Southern India. Occasionally used as a building stone for the construction of temples and palaces, it has been more often employed for the finer decorative work, or for the fashioning of

images. It is extensively used in the ornamentation of temples in Orissa, in the western parts of the Bellary district, Madras, and elsewhere. Other minor uses of similar materials included the manufacture of 'slate' pencils, cups, vases, models, figurines and general bric-à-brac. 'Small idols,' states V. Ball, 'are sold in large numbers at Puri and carried all over India by pilgrims as mementos of their visit to Jagannath', and there is believed to be a trade of considerable extent in the mineral in almost every province, which does not appear in the official returns. The variety agalmatolite is familiar in India in the carved ornaments of the curio shops, and the wares of the travelling Chinese trader, but these are of Cantonese origin.

Steatite has many applications in industrial life. Large slabs are cut into panels for switch boards, table tops, laboratory and kitchen sinks and tanks, as well as linings for furnaces and stoves, for the mineral is a bad conductor of heat and electricity and is very resistant to the action of acids and corrosive melts. Smaller pieces of suitable grades make the tips for gas burners, and the first inquiries for Indian material from abroad were for this purpose. The mineral is also used by tailors for marking cloth and is put to a similar purpose in foundries, and iron and steel works. It is believed, however, that about 90 per cent of the world's output is used in the form of fine powder which is extensively employed as a filler in the paper, textile, rubber, soap and paint industries. It is also used in foundry facings; as a polishing agent for glass, leather, and food grains, particularly rice; as a lubricant; in the manufacture of certain wall plasters; and as a coating for the surfaces of materials such as roofing preparations, which would otherwise stick together when rolled for packing. Added to concrete in small quantities it is said to lessen its water absorption. The purest white varieties, ground to the consistency of flour, form the 'french chalk' of commerce, which is the basis of many cosmetics and toilet preparations. Some idea of the importance of this mineral may be gained from the fact that its annual production in the United States of America is now worth over \$2,500,000, while the annual imports, in addition to this, account for a further \$500,000.

India's recorded production of steatite has now reached over 17,000 tons per annum, and more than half of this comes from Rajputana. A milling plant for steatite has recently been installed at Dausa, Jaipur State, Rajputana. It is described by K. L. Bhola (1935) as having a capacity of 3 tons per hour and producing 100-, 200- and 300-mesh

powders. The first product is sold to soap-makers in the Punjab. The second is used in the manufacture of paper and paints, in the sizing of cloth and the polishing of rice and pulses in India. The third and finest grade is exported, particularly to Holland, Belgium and the Argentine.

Three localities in the Jaipur State have been described by A. M. Heron. At Dogetha, a pure, milky-white kind in one of the highly ferruginous portions of the Raialo limestone has been quarried on a fairly large scale. Near Morra a deposit, mentioned by Hacket in 1880, extends for five miles in the form of richer pockets in a stratum associated with talcose schists. At Gisgarh, the bed is only 2 feet thick and the quality inferior to that of Dogetha. Pure, pearly-white steatite and a poorer grade blotched with grey, are reported to exist in dolomitic limestone at Jeoria, Merwar, by E. J. Bradshaw, while B. B. Gupta mentions deposits of variable quality which were worked near Rikhabdeo and Khandmin in Udaipur. Of several localities in the Central Provinces the best known is the Marble Rocks near Jubbulpore, where a slightly schistose, white to pale green variety, forms steeply dipping pockets in Dharwarian dolomites. The Madras supplies come mainly from the Nellore and Salem districts. In the former, talc rock occurs near Jogipalli, while talc schists associated with mica schists are found on the right bank of the Penner river between Kaluvaya and Thalagapur. Among the occurrences of the Salem district, the bed of compact steatite which crosses the Ishwara Malai and has been extensively worked at Tundagundapalaiyam, deserves mention. White and green kinds occur at Musila Cheruvu and Maddavaram in the Kurnool district, where the shales of the Papaghai group are very magnesian, and, states W. King, 'some of the layers being nothing else but fine grey and greenish steatite'. These deposits were worked on a small scale some twenty years ago and part of the output was sold in the United States of America.

According to Sir Lewis Fermor, soapstone and potstone are found in abundance in certain parts of Bihar and Orissa, but soft chloritic schists and decomposed basic dykes are often used as potstones as well as the true talcose varieties. The latter occur near the sheared margins of peridotite intrusions into Dharwarian slates in the Kolhan, while talc schists are intercalated in the Dharwarian schists of Dhalbhum. 'Talc,' states J. A. Dunn, 'is found in several places associated with the Dalma volcanic rocks.' In Koraikele a small

**TABLE XXXVI**  
**PRODUCTION OF STEATITE**  
*In long tons*

PERIOD	BIHAR AND ORISSA	BURMA	CENTRAL INDIA	CENTRAL PROVINCES	MADRAS	MYSORE	RAJ- PUTANA	UNITED PROVINCES	TOTAL	VALUE
1904-08 ...	...	54	...	764	...	2,605 <sup>1</sup>	...	...	3,423	£ 3,040 <sup>2</sup>
1909-13 ...	1,056 <sup>2</sup>	51	...	2,380	947	...	...	625	5,059	12,619 <sup>3</sup>
1914-18 ...	252 <sup>2</sup>	...	73	7,637	2,033	9	120	671	10,795	22,308
1919-23 ...	901	8	...	5,916	3,248	614	19,441	358	30,486	35,621
1924-28 ...	3,956	27	995	6,594	3,358	388	16,022	525	31,865	48,986
1929-32 ...	1,353	...	336	4,346	942	372	17,454	924	25,727	54,636
<b>Grand Total ...</b>	<b>7,518</b>	<b>140</b>	<b>1,404</b>	<b>27,637</b>	<b>10,528</b>	<b>3,988</b>	<b>53,037</b>	<b>3,103</b>	<b>107,355</b>	<b>177,210</b>

The total production of steatite for the two years ending 1934 was 26,423 tons, valued at £26,557.

<sup>1</sup> Statistics discontinued as untrustworthy in 1907.

<sup>2</sup> Full quantity not stated but reckoned in value.

<sup>3</sup> Small value from Hyderabad included.

industry exists in the mining and working up of talc rock into various utensils. The mineral is secondary to epidiorite, and as it contains much fine chlorite cannot be used as a basis for commercial talc powder. In Seraikela, the mineral used to be worked west of Bara Kadel, where it has been formed by the alteration of an ultrabasic rock. In the Singhbhum district, in 1934, deposits were under exploitation at Khejurdari and Digba, according to A. K. Dey.

In Burma, the mineral occurs in the Axial Group of the Arakan Yoma and Pakokku Hill Tracts, usually in veins associated with serpentine. The best known locality—now abandoned—was reached from Hpa-ang in Minbu district, though it was actually in Kyaukpyu.

A large deposit of steatite of very fair quality was discovered in 1912 by C. S. Middlemiss, in association with Delhi (?) quartzite, near Dev Mori, Idar State, Bombay. It was calculated that two million tons are available in the first 20 feet from the surface, as the bed has been traced for over a mile and has a width of more than 200 feet.

To be acceptable to the trade steatite must be entirely free from gritty impurities caused by quartz, harder silicates or carbonates. Personal inquiries in the London market have led to the conclusion that the failure of the Indian material to obtain a permanent footing there is largely due to two causes: the first, that greenish varieties have been offered and supplied instead of the white ones, and the second, that insufficient care has been exercised in the powdering operations.

## KAOLIN

In addition to its uses in the ceramic industry which have been described already, kaolin, or china clay, has many other applications, which, as far as India is concerned, relate principally to the dressing of cotton fabrics and to the 'filling' of paper. As regards the first, it is significant that over 80 per cent of the imported material reaches Bombay, the centre of the cotton textile industry. For paper-filling the Singhbhum product has completely displaced imported clay in an important group of mills near Calcutta, which consume over 3,000 tons per annum. Kaolin is also used as a filling for articles made of rubber, and in the manufacture of linoleum, paints, soaps, polishes, plasters and medicines. In Mysore, besides being employed in brick making, it is used for 'slate' pencils and marbles. It figures in the



Indian hakim's pharmacopœia as an efficacious specific in the treatment of cholera. To be acceptable to the trade in India, omitting here the requirements of the potter, kaolin must be of a perfectly white colour, of a high degree of suspensibility in water—a property depending largely on its fineness and the shape of its particles—and have very low contents of iron and grit. The methods adopted in attaining these ends in India have been described by F. B. Kerridge (1930), whose opinion that there appears to be no reason why the indigenous production should not fill the greater part of the country's requirements, instead of the 50 per cent it does at present, is certainly correct.

## CHAPTER XII

### MINERAL SUBSTANCES WITH SPECIAL USES: ASBESTOS, MICA, FULLER'S EARTHS, FLUOR SPAR, LITHIUM MINERALS, MONAZITE, RARE EARTH MINERALS, BERYL, STRONTIUM MINERALS, LITHOGRAPHIC STONES AND MINERAL WATERS

#### ASBESTOS

THE term 'asbestos' embraces a number of minerals which all possess the property of splitting into fibres capable of being felted or spun together. They are divided into two groups: (1) Chrysotile asbestos, a hydrated silicate of magnesium, and (2) Amphibole asbestos, which includes the fibrous varieties of tremolite (a calcium-magnesium silicate), actinolite (a calcium-magnesium-iron silicate), anthophyllite, including its relative amosite (a magnesium-iron silicate), and crocidolite or blue asbestos (a silicate of sodium and iron). The first group supplies the raw material for by far the greater proportion of the world's production of asbestos goods and is the more valuable of the two. Most, though not all, of the Indian asbestos so far discovered belongs to the tremolite and actinolite species of the second group. Their fibres, though often of considerable length, are usually too weak and brittle for spinning, though they may possess good insulating and acid-resisting qualities.

Amphibole asbestos has been found at several places in Seraikela State, Bihar and Orissa, but according to J. A. Dunn the Bara Bana deposit is the only workable one. Here the mineral occurs in the shear planes of a serpentine, itself included in granite and traversed by dolerite dykes. The 'logs' of asbestos are frequently up to 14 feet in length and 12 inches in diameter, but the material so far found is too brittle for spinning. Production commenced in Seraikela in 1921, and the total quantity extracted up to the end of 1929, when working

ceased, was 311 tons. A revival occurred in 1932, when 90 tons were obtained, and again in 1934, when 20 tons were won.

Amphibole asbestos occurs at many localities in Mysore and appears generally to be an alteration product of ultra-basic rocks in close proximity to granitic and gneissose intrusions. At Kabbur in the Hassan district, long fibrous sticks several feet in length are obtainable, but the mineral has the usual defects of brittleness and lack of tenacity. The district has yielded 3,467 tons at intervals between the years 1906 and 1929, when production stopped. The Bangalore district of the same State furnished a total of 176 tons in 1920 and 1921.

A total of 84 tons of asbestos has been obtained in small amounts spread over a number of years from Tumkhera Khurd, in the Bhandara district of the Central Provinces.

C. S. Middlemiss has drawn attention to the presence of amphibole asbestos in association with magnesite-serpentine and other rocks between Kundol and Dev Mori, Idar State, Bombay.

Small parcels of 5·7 and 6 tons respectively appear in the returns from Ajmer-Merwara, Rajputana, for the years 1927 and 1931. These may have come from Kolai, where A. M. Heron found workings displaying stringers ramifying through serpentine enclosed in crystalline limestone. Asbestos also occurs at Sendra in the same district and at Delawas and Guda in Alwar.

The most promising occurrence is near Brahmanapalle in the Cuddapah district of Madras, where thin veins of chrysotile asbestos occur in dolomitic limestone, which C. S. Fox states belongs to the Vaimpalli stage of the Papaghni series of the Cuddapah system, and in an intrusive dolerite along its serpentinized zone of contact with the limestone. The mineral is of excellent quality, and between 1924 and 1934, 205 tons have been removed from the district.

Dr A. L. Coulson investigated the asbestos deposits of the Cuddapah and Kurnool districts in 1932. He found that the Brahmanapalle-Lopatanutula occurrences extend over a distance of  $9\frac{1}{2}$  miles. The asbestos zone is rarely more than three feet thick and is made up of numerous cross-fibred, chrysotile veins, up to three inches in width, anastomosing through serpentinous magnesian limestone. Smaller deposits of a similar type exist at Rajupalem, in the Kamalapuram taluk of the Cuddapah district, and near Malkapuram and Johrapuram in the Kurnool district. Dr Coulson concluded that the asbestos of these serpentinized magnesian limestones, which occurs

nearly always above, and only exceptionally below, their contacts with intrusive dolerite sills, owes its origin to hydrothermal solutions which accompanied the dolerites themselves.

It is impossible to enumerate here the multitudinous uses to which asbestos is put, and it must suffice to state that its fire, weather and acid resisting properties make it an indispensable material in modern civilization. After dressing in special machinery and grading, the fibres are used for a variety of purposes without further treatment, such as for insulations of all kinds, the manufacture of heat-resisting materials, of brake-band linings, gaskets and clutch facings, the filtration of acids, and packing for every type of steam and water valves. The fibres are spun into yarns and woven into ropes, tapes, felts and cloths; the shorter ones are made into millboards, paper, lagging and compositions. Mixed with cement and other substances, asbestos is used in the manufacture of roofing tiles and slates, building sheets, ceilings, partitions, floorings and fire-proof coverings for woodwork. Such materials find increasing outlets in building construction.

India imports large quantities of asbestos goods, and the small quantity of the raw mineral which reaches the country is no guide whatever to the size of her market for them. Many of these articles are manufactured from the shorter grades and less valuable fibres, and there seems no reason why they should not be manufactured in the country, provided the special machinery devised for the purpose is adopted.

Careful prospecting for further deposits of the chrysotile variety is required. Canada produces about 67 per cent of the world's supply of this material in a total world production of all kinds of asbestos of 376,000 tons in 1930, and the bulk of the raw fibre quarried in that country averages only one-quarter to one-half inch in length. There are large areas of rocks in India similar to those that are the home of the great chrysotile deposits of Quebec, and these should be more carefully examined for small veins, which are easily overlooked on cursory inspection. Too much attention has been paid in India in the past to the length of the fibres, but extreme length is of no advantage, as most of the asbestos of commerce comes from very narrow cross-fibre veins. Commercial value depends more on such properties as tensile strength, fineness and flexibility, colour, and heat and electrical resistance.

For the five years ending 1930-31, the average annual imports of asbestos of all kinds into India were valued at Rs. 31,63,838. Of this total, raw asbestos accounted for Rs. 162; manufactured asbestos in the form of packing for Rs. 5,40,588; and all other kinds of manufactured goods for Rs. 26,23,088.

### MICA

Although it is one of the commonest rock-forming minerals, occurrences of muscovite mica in the sizes and qualities demanded by the market are only found in the pegmatite veins of a few restricted areas, while the phlogopite variety of Canada is associated with pyroxenite dykes. The chief producing countries are India, the United States of America, Canada and, in later years, the Union of South Africa. The total value of the mica yielded by the three first named countries during the first 29 years of the present century, 1900-28 inclusive, was £14,572,212, and of this India was alone responsible for £11,188,062 worth, or 76 per cent.

Mica finds its chief use in the electrical industry as an insulating medium. For this and other purposes, its perfect cleavage, transparency and lack of colour in thin sheets; its flexibility, toughness and non-conductivity of electricity and heat; its resistance to temperature changes and chemical decomposition, render it indispensable. Mica mining has indeed grown with the advance of electrical engineering; and through its unique combination of properties the developments of motor transport, aeronautical science and radio-telegraphy have been made possible. Sheet mica is also used for the fronts of stoves and furnaces, for lamp chimneys, etc. The ground mineral is employed as a drying powder for sticky compositions, such as roofing materials, in the manufacture of pipe and boiler lagging, as a decorative substance for wall papers, and as a lubricant.

The commercial value of mica is greatly affected by its cleavage, or the ease with which it can be split into flat sheets free from irregularities, by its hardness and flexibility, by its colour, by its freedom from specks, stains and inclusions and last, but by no means least, by the sizes of the sheets themselves. As it comes from the mines the raw mineral needs much preparation before it can be exported. After the removal of broken and flawed pieces, the sheets are trimmed, a sickle being used for this purpose in Bihar and shears in Nellore, the product being then known as 'dressed block'. The wastage in this

process alone amounts to between 70 and 80 per cent. The dressed mica is next sorted into the various market sizes, of which there are ten, ranging from No. 6, in which the area of the included rectangle measures 1 to  $2\frac{1}{2}$  square inches, up to 'extra specials' of 60 to 80 square inches. After sizing comes the grading process, in which the sheets are classified according to their freedom or otherwise from stains and inclusions. Nine quality grades, ranging from clear to densely stained, are recognized on the London market. Most of the larger sizes and better qualities are exported in block form. Over 80 per cent of the exports, however, consist of splittings, made by separating the smaller sizes into the thinnest possible films, one thousand films to the inch being the usually accepted standard. This operation, which demands delicacy of touch and remarkable dexterity, is usually done by women, using a sharp-pointed knife and trained to the work from childhood. The pre-eminent position they have attained in this craft is shown by the foreign block mica which is now sent into India from other countries, to be exported again in the form of fine splittings. For the five years ending 1932-33, such imports averaged 28 tons per annum and were worth Rs. 60,672. Mica splittings are used in the manufacture of micanite, plates of any desired thickness being built up and compressed with shellac as the binding agent. By steaming, pressing and rolling, such material can be moulded into any desired shape.

The great mica belt of Bihar is a strip of country, some 12 to 14 miles broad and over 60 miles long, which runs in an east-northeasterly direction through the junctions of the Gaya, Hazaribagh and Monghyr districts, from Champaran in the west to Jha-Jha in the east. It coincides with the band of Dharwarian schists and associated gneissose granites forming the hilly country leading down from the Hazaribagh plateau to the Gangetic plain. Both rock groups are penetrated by the mica-bearing pegmatites, generally along their foliation planes, the profitable ones being confined to the schists. The pegmatites are nearly always of lenticular forms, and of varying lengths, up to a maximum of 1,500 feet, with steep dips and thicknesses from a few inches to 100 feet or more. They are coarse aggregates of quartz, felspar and muscovite mica, with some biotite and accessory minerals such as garnet, tourmaline, apatite and beryl. They frequently exhibit a zoned structure with a quartz core and feldspathic margins, and there is a tendency for the mica 'books', which exceptionally attain great

sizes, to be found in pockets at the junctions or near the contacts with the country rock. The exceedingly irregular distribution of the mica in the veins themselves accounts to some extent for the primitive methods usually employed in mining for it, many of the workings being merely winding holes following on from one 'book' to the next. There are however some well-equipped properties, though it is only within recent years that systematic stoping has been undertaken. In the pegmatites of Jorasemar, near Koderma, which were mined under the direction of the Geological Survey of India on behalf of the Ministry of Munitions between 1917 and 1919, the mica contents averaged about 6 per cent of the total rock excavated, but less than 1 per cent represented material of commercial quality. C. S. Fox believes that some of the mica-bearing pegmatites are not primarily of igneous origin, but rather the recrystallized products of the mica schists themselves, localized in the arches and troughs of folds in certain fault zones where great crushing has been developed, or at places where static pressures must have been very large.

The Bihar mica belt probably yields over 80 per cent of the Indian production, and most of the remainder comes from the Nellore district of Madras, the mica-bearing regions of which have been divided by A. Krishnaiya into four zones, named after the towns of Gudur, Rapur, Atmakur and Kavali respectively. The belt is sickle-shaped, tapering to the south-east and to the north-north-east; the southern point being nine miles to the south-south-east of Gudur and the northern one, nine miles north-north-east of Sangam. The central portion, widest in the Rapur taluk, carries most of the mines. The country rock is an Archæan schistose complex in which sheets, lenses and large masses of pegmatite are of frequent occurrence. The latter are often very coarse, and not infrequently the quartz and felspar are intergrown in the form of graphic granite while tourmaline, garnets, apatite and beryl are again the commoner accessory minerals. Much of the area is concealed by recent formations, which has led to mining in large open-cast excavations, though some of the bigger mines are worked on modern lines. Crystals of muscovite measuring 15 feet along the foliæ and up to 10 feet across the basal plane have been obtained from this field, but such immense sizes are very exceptional. The average thickness of the mica-bearing pegmatites is from 10 to 15 feet, and their length from 30 to over 1,200 feet. G. H. Tipper has recorded that their commonest form is that of a lens, or of a

series of connected lenses, arranged *en échelon*, or, again, of long irregular masses. Dr P. K. Ghose stated in 1933 that the deepest mine, the Shah, was at that time only 290 feet below the surface, and that nothing is known of the behaviour of the deposits at greater depths. Ghose adds that most of the mines which have followed scientific methods of development have been financially successful. Mica has probably been mined in the Bihar belt for centuries to supply Indian requirements for ornamental, artistic and medicinal purposes, but in Nellore it commenced in a small way about 1887. Much of the Nellore mica has a green colour and is easily distinguished from the so-called 'Bengal ruby' variety of Bihar.

Marketable mica has also been won from the Salem, Nilgiri and Malabar districts of Madras, from Ajmer-Merwara and other parts of Rajputana, where Dr A. M. Heron, writing in 1935, states that the chances of finding deposits of real importance are slight. The soft, amber-coloured phlogopite occurs in the Eraniel taluk of Travancore.

Statistics relating to the actual production of mica in India are thoroughly unreliable, as the quantities exported through the customs in a particular year have sometimes been twice as great as the reported output of the mines. Since the enactment of legislation in 1930 regulating the mica trade in Bihar and Orissa, some slight lessening of the gap between the two sets of figures has become apparent. As the exports in 1934, however, again exceeded the reported production by 66 per cent, much still remains to be accomplished in this respect.

India's total exports of mica between 1897 and 1934 were 98,675 tons, valued at £14,051,039, and her best customer has been the United Kingdom. Of late years the proportion so taken has fallen from over 75 per cent to 40 per cent, while the United States of America, which commenced by buying about 15 per cent of the exports, has taken over 37 per cent during the past decade. Germany follows next, but her buying has been erratic and in the last quinquennium accounted for 8 per cent of the supply (see Table XXXVII).

Attempts to manufacture micanite in India have not been successful, though her virtual monopoly of shellac production should have been helpful in this respect. There is a steady demand for pulverized mica in the markets of some countries, and in view of the enormous quantities of waste material available, it is surprising that its preparation is not carried on in India. The commanding position



held by the country in the mica trade of the past, and the manual perfection reached by its splitters, are not reasons for relaxation of efforts to improve mining and marketing methods, or to delay the introduction of finishing processes. Increased competition from other countries will have to be faced in the future, and in this connexion the development of a scheme for co-operative marketing, advanced by G. V. Hobson, should help to remove existing abuses and to stabilize selling prices at remunerative levels.

TABLE XXXVII  
EXPORTS OF INDIAN MICA

PERIOD	TONS	VALUE	DESTINATION		
			United Kingdom	United States of America	Germany
		£	%	%	%
1897-1902 <sup>1</sup>	5,751.9	465,678	77.4	15.5	5.4
1903-1907 <sup>1</sup>	8,151.25	827,016	52.8	14.7	22.7
1908-1913 <sup>1</sup>	13,614.2	1,322,486	55.4	16.9	16.1
1914-1918 <sup>1</sup>	12,396.55	1,915,073	Restricted to United Kingdom		
1919-1923	14,650.0 <sup>2</sup>	3,166,655	53.2	37.5	4.8
1924-1928	21,635.4 <sup>3</sup>	3,689,651	40.6	37.2	12.0
1929-1933	17,834.4	2,212,933	41.3	32.4	8.1
1934	4,641.3	451,547	42.6	31.9	10.8

GRAND TOTAL (1897 to 1934) = 98,675 tons, valued at £14,051,039.

### FULLER'S EARTHS

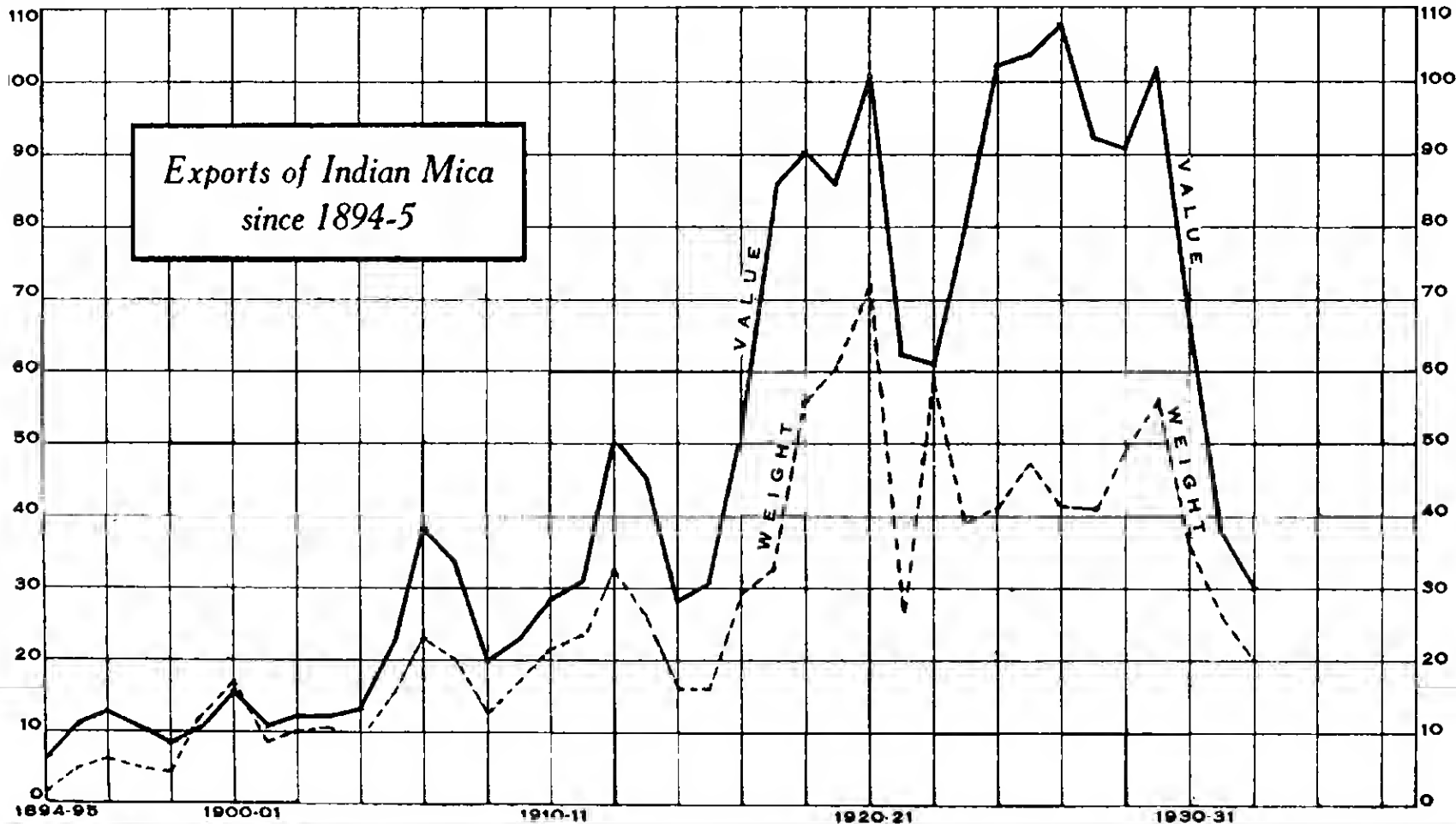
Fuller's earths are soft, usually non-plastic, light coloured earths, consisting chiefly of hydrated silicates of aluminium with variable quantities of lime, magnesia, alkalis and iron oxide, which possess the power of absorbing grease and were at one time used by fullers for cleansing cloth. They are still widely employed in India as

<sup>1</sup> Fiscal years.      <sup>2</sup> Figures for 1921 represent 9 months only.

<sup>3</sup> Divided as to 83.2 per cent splittings and  
16.8 per cent block mica.

LAKHS OF  
RUPEES

HUNDRED  
TONS



Graph 20

detergent agents for washing clothes, etc., and they also form part of the edible earths which are sold in the bazaars of most places. Such earths have the property, in common with bauxite, of absorbing the colouring matter and other impurities from both mineral and vegetable oils and are used for this purpose in some countries. Other uses of these materials include their application as carriers for pigments in the paint and allied trades, and as fillers for paper and soap.

Steady supplies figure in the mineral returns from the Bikaner, Jodhpur, and Jaisalmer States of Rajputana, from Hyderabad, Sind and from Mysore, with smaller quantities from the Jubbulpore district of the Central Provinces. The total recorded production usually fluctuates between 3,000 and 4,000 tons per annum, but in 1934 8,526 tons, valued at Rs. 90,268, were won. The Rajputana product, which is known as *Multani mutti* (Multan earth), is a yellowish, unctuous clay of Nummulitic age. It is quarried at Mar, near Kolaith in Bikaner, and near Barmer and Kapuri in Jodhpur, and sent to Multan and other towns of Northern India for distribution. Another locality exists at Mandar in Jaisalmer, whence considerable quantities are removed for sale. The Central Provinces material comes mainly from Lower Vindhyan rocks at Katni.

According to L. K. Bhola (1935), seams of fuller's earth, 6 feet in thickness, are worked by underground methods, to a depth of 130 feet below the surface, near the Palana colliery in Bikaner State. The output in 1933 was about 1,000 tons and the material is marketed in the Punjab and the United Provinces.

## FLUOR SPAR

Fluor spar or fluorite, the fluoride of calcium, is consumed in large quantities by the basic, open-hearth process of steel manufacture, for it increases the fluidity of the slags and helps to remove objectionable elements, such as sulphur and phosphorus. As the output of Indian steel has grown, the imports of fluor spar have increased from about 300 to 400 tons annually during the years 1909-13 to upwards of 1,500 tons per annum at the present day. Though it is widely distributed in small quantities, large deposits of the mineral are rare, and as yet, not one of commercial importance has been discovered in India, though it is known to occur in several localities. Thus it is found at Barla, Kishengarh State, Rajputana, in a vein with quartz and calcite, traversing gneiss; in certain wolfram-bearing quartz veins of the

Tavoy district, Burma, and of Degana, Jodhpur State, Rajputana; in association with the arsenic ores of Chitral; accompanying the copper and lead ores of Sleemanabad, Jubbulpore district, and the lead ores of Chandi Dongri, Nandgaon State, Central Provinces; in small quantities in the Bhandar (Upper Vindhyan) limestone of Rewah; as a very rare accessory in the granite-gneiss of Singhbhum; in the Erinpura granite of Mount Abu, and in the Idar granite of Sirohi State, Rajputana.

In addition to its uses in the steel industry, fluor spar is employed in the manufacture of opalescent glass and in the enamels for metallic and sanitary wares. It is the chief source of hydrofluoric acid in the chemical trade, and the finest varieties are bought by opticians for conversion into prisms and lenses.

### LITHIUM MINERALS

Lepidolite or lithia mica, a complex hydrated silicate of aluminium, potassium and lithium containing fluorine and other elements, with a lithia content ranging from 2 to 6 per cent, has long been known as a constituent of certain Indian mica-bearing pegmatites and vein granites. F. R. Mallet in 1874, though not finding it widely distributed in such rocks in the northern Hazaribagh region of Bihar and Orissa, proved its existence in considerable quantities in some places, as, for example, in a dyke south-west of Pihira where it occurs in irregular, scaly masses of violet-red to greyish violet colours. The first variety contained 3.71 per cent of lithia. Again, about a mile south of Manimundar in the same area, the sides of a hillock are strewn with blocks of the mineral, one of which was estimated to weigh about 8 cwt.

In 1934, H. Crookshank found boulders of lepidolite over a distance of about one mile, along the base of a greenstone ridge, south of Mundval in Bastar State, Central Provinces, derived from pegmatites which intersect the greenstone itself. Hundreds of tons of the mineral, which contains 3.34 per cent of lithia, are available here with a probability of much larger supplies. Should a demand for lepidolite or for lithium salts arise in the future in India, these deposits might prove of economic importance.

The mineral itself is used principally in the glass industry as an ingredient in the preparation of heat-resisting opal, white and flint glasses. It has also been employed in the manufacture of porcelain, particularly for insulators and sparking-plugs.

Lithium chloride, the salt from which metallic lithium and its compounds are made, was previously prepared mainly from the minerals spodumene, a silicate of aluminium and lithium, or amblygonite, a fluo-phosphate of the same metals, as both these minerals contain more lithium than lepidolite itself. In recent years, however, chemical methods have been successfully developed in Germany which commence with lepidolite as the raw material.

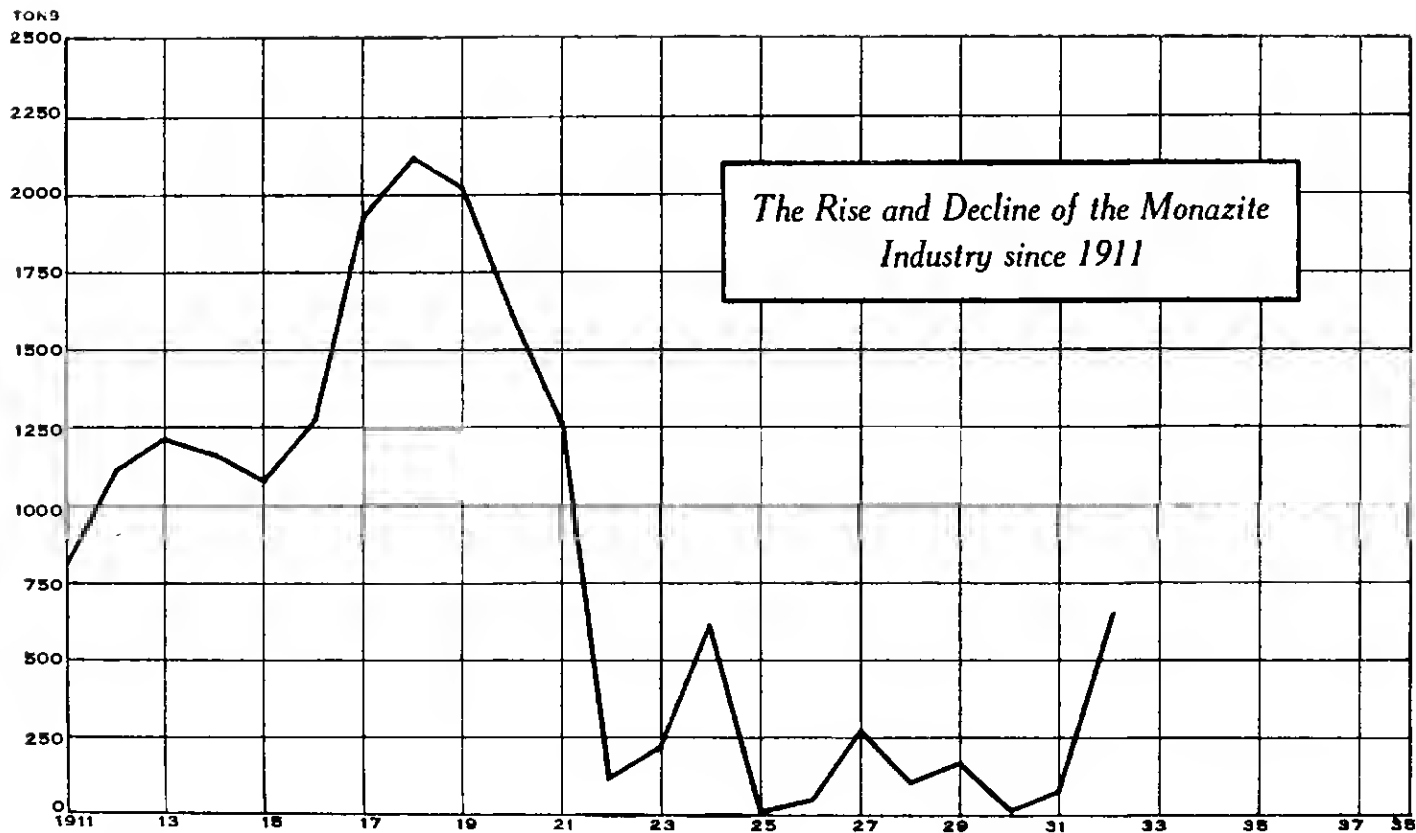
Amblygonite has been found in small quantities in Kashmir, in a valley close to the Sapphire Mines, but the isolation of this locality, even if the mineral were obtainable in large amounts, would probably prevent its commercial extraction.

Lithium is the lightest metal known, and its chemical and physical properties resemble those of the alkali and alkaline earth groups, for it is a member of the former, which also includes sodium and potassium. Its marked affinity when in a molten condition for other elements, has led to its use for the removal of impurities and occluded gases in the refining of nickel, copper and other metals. Alloyed with aluminium, magnesium and small quantities of other metals, it increases their hardness and imparts other useful properties, while alloys of lead with lithium and small amounts of calcium are stated to have been employed as bearing metals for the rolling stock on German railways, a development brought about by the shortage of tin, previously used for hardening lead, during the war of 1914-18.

Lithium salts are valuable curative agents in the treatment of diseases caused by uric acid, while the hydroxide finds an expanding field in the manufacture of alkaline accumulators, of which it is said to prolong the life when added to the electrolyte.

### MONAZITE

Monazite, a phosphate of the rare earths of the cerium group, is widely distributed in India, where it is usually associated in situ with pegmatites. For example, it occurs with pitchblende and columbite in a pegmatite at Pichhli, Gaya district, Bihar and Orissa, and in similar rocks traversing the gneisses of south Travancore it has been found in small yellowish and brownish grains. The processes of natural concentration have given rise on the shore, between Cape Comorin and Quilon, to sand deposits of sufficient richness to be worked for commercial purposes, while G. H. Tipper states that the sand dunes in the vicinity also contain the mineral, accumulated therein by wind



Graph 21

action. Their discovery in 1909 was due to C. W. Schomberg, and later work resulted in the location of five major deposits, at Liparam, Pudur, Kovilam, Warkalli and Nindikarai, respectively. Exploitation commenced in 1911, and from that date until the end of 1934, 19,297 tons of monazite, valued at £ 510,370 had been shipped by the Travancore Minerals Ltd. and its predecessors. The mineral is accompanied by large quantities of ilmenite, quartz, garnet and zircon, and is extracted by washing, followed by magnetic separation. Its value depends on the proportion of thorium which it contains, and which may vary from 5 to 10 per cent. This is the raw material for the preparation of thorium nitrate used in the manufacture of incandescent gas mantles, which yields the oxide, thorium, on ignition. The oxides which form the skeleton of the mantle are stated to be derived from a mixture containing about 99 per cent of thorium nitrate and 1 per cent of cerium nitrate. Thorium finds another application in the manufacture of certain types of thermionic valves, while the cerium by-products give metallic cerium, ferro-cerium and cerium oxide. The cerium-iron alloy is a common article of everyday use, and furnishes the spark in pocket lighters and similar devices. Pyrophoric alloys of this type are used as tips to tracer shells which, igniting as the projectile is fired, enable its path to be followed. Cerium compounds are also used in searchlights, in the carbons of ultra-violet lamps, and to a certain extent in pharmacy. Mixed with titanium oxide in the proportion of five parts of titanium to one of cerium, the oxide imparts a bright canary-yellow colour to glass. Mesothorium, a radio-active substance of short life, is another by-product recovered in the course of thorium nitrate separation. For the other rare elements found in monazite no commercial uses of importance appear to have been discovered as yet.

Prior to 1911 the world's supplies were almost entirely derived from Brazil, but India obtained the lead in 1914 and probably kept it until the decline in the demand supervened as a result of the spread of electricity for lighting purposes, and reduced production to a fraction of its former figures. For the years 1911-15 inclusive, output was fairly steady at about 1,100 tons per annum. It then rose rapidly and passed its peak of 2,118 tons, valued at Rs. 8,82,285, in 1918. A severe fall occurred in 1922, and the average annual production over the decade ending 1931 only amounted to 172.5

tons. The export of the sand was suspended in the fiscal year 1929-30, but in 1932 production increased to 654.3 tons, valued at £6,147, and to 1,009 tons, valued at £3,885, in 1934. In Graph 21 the annual fluctuations of production since its commencement in 1911 are shown.

India's monazite deposits are the largest in the world, while as regards quality and thorium content the Travancore mineral easily comes first, so that should a renewed demand for thorium or for salts of any of the elements of the cerium group arise in the future, there is little doubt that production would again expand to meet it. From 1922, the decline in the monazite output has been compensated to a considerable extent by the increased tonnages of ilmenite which have been won, furnishing yet another example to the many already known cases in which an apparently worthless by-product of a mineral industry has in the course of time become its mainstay.

### RARE EARTH MINERALS

In addition to monazite, and certain minerals containing rare earths described under NIOBIUM and TANTALUM, it remains to mention others which are known to occur in India. The uses of cerium have already been described under MONAZITE, and for most of the other rare earth elements belonging to the same general group, no outstanding applications appear to have been found at present.

Allanite, a complex, hydrated, monoclinic orthosilicate of the epidote group, containing calcium, aluminium, iron, cerium, didymium, lanthanum and the elements of the yttrium group, has often been recognized under the microscope in sections of various igneous rocks. It has been found in larger quantities in coarse pegmatites at Sankara, Vadlapudi and Tirupundla mica mines in Nellore, and is also recorded from near Palni in Madura district. C. S. Middlemiss states that it occurs in large quantities in a pegmatite at Karadikuttam Pattiam-bodikutru, Madras district. He also described an allanite-bearing aplite vein cutting calc-gneisses, two miles north by east of Khed Brahma, Idar State, Bombay, in which granular, greenish-black allanite with sphene and a little zircon is prominent in certain bands of rock, six inches to one foot thick, following a rough parallelism in the veins.

Gadolinite, a silicate of beryllium, iron and the yttrium earths, was discovered by Baidyanath Saha in 1903. It accompanies tour-



maline and cassiterite in a pegmatite at Hosainpura, Palanpur State, Bombay.

A mineral related to xenotime, a phosphate of yttrium and allied elements, has been reported from the apatite-magnetite deposits of Ara Buru, Manbhum, Bihar and Orissa.

Various other minerals containing niobium and tantalum occur in India. Samarskite, a heavy black niobate and tantalate of uranium, iron and the metals of the cerium and yttrium groups, has a characteristic splendid lustre and a conchoidal fracture. It has been found in pegmatites of the Bangalore district, Mysore, but the largest occurrence is at the Sankara mica mine, Rapur taluk, Nellore district, Madras. Here a great lenticle of pegmatite has been segregated into large masses of its constituents, and a central boss of quartz is surrounded by massive white felspar. A pinkish-brown felspar also occurs, and the samarskite masses, according to G. H. Tipper, who visited the mine in 1910 and 1911, vary in size from small fragments up to pieces weighing 200 lb., and are always wholly or partly embedded in this material. Analysis of the mineral by the Imperial Institute showed 39.76 per cent  $\text{Nb}_2\text{O}_5$ ; 13.64 per cent  $\text{Ta}_2\text{O}_5$ ; 12.09 per cent  $\text{U}_3\text{O}_8$ ; 15.8 per cent  $\text{Er}_2\text{O}_3$  and  $\text{Y}_2\text{O}_3$ ; and 0.61 per cent  $\text{La}_2\text{O}_3$ . The mineral is strongly radioactive. A total output of 2 tons 6 cwt. of samarskite was reported from this locality for the years 1913-14.

Sipylite, a niobate of erbium and other rare earths, also occurs at this and other localities in Nellore. Æschynite, a niobate and titanate of the cerium metals, has been obtained from a pegmatite in the Eraniel taluk of Travancore. Hatchettolite, a tantaloniobate of uranium, comes from the same locality as the latter and from the Kadavur zemindary, Trichinopoly, Madras.

## BERYL

Beryl is a silicate of beryllium and aluminium with the formula  $3\text{BeO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ , and its gem variety, known as the aquamarine, is described under GEMS. Theoretically, the mineral contains 14 per cent of beryllium oxide, which is equivalent to a content of metallic beryllium of only 5 per cent. In practice, owing to impurities in the mineral and losses in extraction, it is doubtful if much more than 3 per cent is recoverable. Yet beryl, itself a rare mineral, is the only practicable source of beryllium at present known. It is usually

found as green, yellow, or bluish, translucent to opaque hexagonal crystals, which often attain large sizes.

The metal possesses many valuable properties, and although it is only two-thirds the weight of aluminium, it is at the same time hard and strong. It forms alloys with copper, nickel and iron, which would be of great service if they could be produced cheaply enough. Its addition to copper increases its strength after suitable heat treatment, and bronzes made in this way show much resistance to fatigue and certain forms of corrosion. Springs made of such materials have been tested in aeroplanes and motor cars. Mr T. Crook of the Imperial Institute states: 'It is claimed that a copper alloy with 2 to 2½ per cent of beryllium yields non-sparking tools which may obviously have many important applications.' The industrial prospects of metallic beryllium and its alloys are certainly attractive, but with its present price of approximately £19 per pound developments are naturally very slow.

The more important beryl deposits of India are those of the mica-bearing pegmatites of Bihar and Orissa, of Nellore in Madras and of Ajmer-Merwara in Rajputana. Messrs Fox and Hobson, in 1929, estimated an annual production of 3 to 4 tons from the Koderma forest area of Bihar and Orissa, and of 5 tons from the mica belt of Nellore, presumably as by-products of mica mining, estimates which E. L. G. Clegg thinks could probably be greatly exceeded in a comparatively short time. The Nellore occurrences have been the subject of a special study by V. S. Swaminathan (1928), who states that only in the Lakshminarayana, Kelly, Palmita and Kubera mines is beryl found in any quantity. K. L. Bhola (1934) has reported on the deposits of Ajmer-Merwara, the most important being those of Tehari, where the mineral is found very irregularly distributed through the quartz of a lenticular, mica-bearing pegmatite, in crystals up to 5 feet in length, and of Besundni, where in an extremely coarse-grained pegmatite, from 75 to 100 feet thick, prodigious columnar crystals occur, from 1 foot to 10 feet across, extending in some cases for 15 to 20 feet, and one of which alone yielded 15 tons of the mineral. Many other localities of lesser importance are known.

One ton of beryl was extracted from Jaipur State, Rajputana, in 1930. In 1932, Ajmer-Merwara yielded 281 tons, which rose to 324 tons in 1933, and fell again to 55 tons in 1934. The mineral, which

contains from 12.34 to 13.35 per cent of beryllium oxide, is shipped to Germany and the United States of America for treatment and is stated to be delivered in Hamburg at £10 per ton, c.i.f. The cost of production in Ajmer-Merwara varies between Rs. 35 and Rs. 60 per ton, delivered at the railhead.

### STRONTIUM MINERALS

Celestite, the sulphate of strontium ( $\text{SrSO}_4$ ), an ortho-rhombic mineral which resembles barite in crystal habit, but from which it is easily distinguished by its lower specific gravity and its crimson flame reaction, has been reported from two localities in India. W. T. Blanford states that it was found by F. Fedden scattered sparingly, in crystalline lumps about the size of walnuts, over the surface of the Khirtar limestone hills of Kohistan in western Sind, especially east of the range to the eastward of Thana Bula Khan. A. B. Wynne found the same mineral in red clays of Tertiary age near Surdag, Kohat district, North-West Frontier Province, but it is not believed to be abundant in this locality.

Strontium compounds are used in sugar refining and in the preparation of signal flares and fireworks. They also have limited applications in pharmacy and in glass manufacture. No statistics are available to show the quantities which are imported into India.

### LITHOGRAPHIC STONES

Lithography is said to have been introduced into India in 1822 by T. N. Rind, who was afterwards placed in charge of the Government Lithographic Press. Writing in 1881 on the general character of lithographic stones, V. Ball made the following remarks: 'Limestones suitable for lithographic purposes are not of wide distribution; the combination of qualities requisite are not often found united. The best stones are compact and uniform in texture, and are free from veins, flaws and spots; they are generally of light colours, for although stones of dark colour can be used for certain purposes, for others it is necessary that the lithographer should have a light ground to work upon.' He also showed how the applicability of the lithographic process to the reproduction of the vernacular writings, when types were not available, led to its extension and widespread adoption all over the country, while the great cost of stones imported from Europe led to trials of stones of Indian origin. Ball quotes a number of

localities where more or less suitable limestones may be obtained, and many of them are from rocks of Vindhyan age, though the Jurassic and younger rocks of Jaisalmer, Cutch and the Punjab are also included. A fuller list is given in La Touche's *Bibliography* though he adds: 'No thoroughly efficient substitute for the lithographic stone imported from Germany has yet been found in India, but stone that answers the purpose fairly well has been met with at several places.' During the war, when the supply of German stones entirely ceased, experiments with various Indian materials were made, and although some of these proved suitable for the rougher kinds of work, on the whole their performances did not approach those of the finer qualities of the German and Austrian stones, and it is highly probable that as soon as these became available again they resumed their old position in the Indian market. Although the number of presses using lithographic stones in India is undoubtedly large, the life of a good stone is a lengthy one, while the spread of rotary presses using zinc plates instead of stones has tended to further limit the demand for the natural material.

### MINERAL WATERS

In his account of the thermal springs of India published in 1882, Dr T. Oldham stated that 'in the majority of instances these remarkable outbursts of water, at a temperature considerably above that of the waters or even of the atmosphere in the neighbourhood, often charged with various gases and emitting strong odours, have been endowed by the superstitious and ignorant with wondrous virtues, or have been supposed to be the result of some miraculous interposition of divine energy'. Oldham's list, which is admittedly far from complete, contains the names of 298 separate localities of hot springs, and to these T. D. La Touche added a further 43 localities in 1918, remarking that these do not include all the hot springs, but only those which are reported to possess some medicinal value, or are charged with mineral matter. The following note on mineral waters was written by Sir Thomas Holland in 1908, but it applies with equal force today, and is therefore quoted in full:

'One curious feature in connexion with Indian minerals is the neglect of our numerous hot and mineral springs. To what extent the value of these is purely fanciful is a matter of small concern for the time being; for whether they have the medicinal properties claimed

for them or not, there is no doubt that well-advertized mineral waters have an economic value, and numerous varieties from Europe and Japan are scattered over India and brought to the continual notice of the travelling public in all railway refreshment rooms. Natives of India have for many ages recognized a value in mineral waters and in the hot springs which are often charged with more than usual quantities of mineral matter. In many cases, these, like most unusual natural phenomena, have become sacred to the Hindus, and have consequently become places of resort for pilgrims from great distances. Of instances of this sort may be mentioned the hot springs at Manikarn in Kulu, where the pilgrims cook their rice in the hot springs emerging in the shingle beds close to the ice-cold stream of the Parbatti river. The hot water is also led into the neighbouring temple and rest-house for baths, being supposed to be of value for rheumatism. At Lasundra in the Kaira district, and at Vajrabai in the Thana district, Bombay Presidency, springs of sulphurous water, having a temperature of  $115^{\circ}\text{F.}$ , are also resorted to by Hindu pilgrims. Hot springs, often sulphurous, are common throughout the Tertiary areas of Sind and Baluchistan on one side, and of Assam and Burma on the other side of India, the distribution being similar to the distribution of petroleum. Other springs occur along the foothills of the Himalayas, in the Kharakpur hills, etc., sufficiently well distributed to permit of easy transport.'

The springs of Jawalamukhi in the Kangra district contain an alkaline iodide and are used locally in the treatment of goitre. Others at Tuwa, Panch Mahals, Bombay, as well as being very sulphurous are highly radio-active. Other springs with comparatively high emanations of this kind occur at Vajrabai and Unei, in the Thana and Surat districts respectively. Sir Lewis Fermor has divided the mineral springs of Bihar and Orissa into six geographical groups, each of which appears to present distinct properties and to be worthy of study in the event of attempts to turn these waters to commercial account. The waters of a spring at Sipri, Gwalior State, have been bottled and marketed by a Bombay firm, while those of Sitakund, near Monghyr, in the Kharakpur hills, are utilized by a well-known Calcutta house.

## PART IV

### GEMS AND SEMI-PRECIOUS STONES

## CHAPTER XIII

GEMS: AQUAMARINE, CHRYSOBERYL WITH PHENACITE AND EUCLASE, DIAMOND, FIBROLITE, GARNET, IOLITE, KYANITE, PERIDOT, RUBY, SAPPHIRE, SPINEL, TOPAZ WITH DANBURITE, TOURMALINE AND JACINTH

### AQUAMARINE OR BERYL

BERYLS were produced in India about 400 B.C. according to S. Ball. Strabo mentions their use in the ornamentation of Indian drinking cups (45 B.C.—A.D. 21) and Pliny regarded India as the chief source of the gem in his time. Of more substantial evidence however, are the beryl ornaments of the Bhattiprolu stupa dating from the Andhra dynasty (220 B.C.—A.D. 236).

Aquamarine is the transparent greenish or bluish-green variety of beryl, the same mineral which when of an intense green colour is known as the emerald. Stones of blue and sea-green shades were mined in the early decades of the nineteenth century at Padyur in the Coimbatore district of Madras, where they occur in a drusy vein of graphic granite cutting mica schist. An account of the workings was given by Leschenault de la Tour (1822). Slender, pale blue crystals, over two inches in length, occur in the great pegmatite dyke at Sakangyi, Katha district, Burma.

Pale green, hexagonal crystals of beryl are common in the mica-bearing pegmatites of Ajmer-Merwara, Bihar and Nellore, where they often attain huge dimensions, specimens having been measured with diameters ranging from six inches to one foot. They are too fissured and flawed and of too poor a colour to be of any value for cutting into gems.

Coarse beryl, too cracked and clouded to furnish aquamarines, is now mined on a large scale in Rajputana and exported for use in the preparation of metallic beryllium and its alloys. (See BERYL.) Some of the necklaces of large, semi-transparent, irregularly clouded beads of pale blue and green colours, sold by the Jaipur jewellers,

may be made from better quality material of this class, according to Dr A. M. Heron.

The yellowish green 'aquamarine-chrysolite' occurs with bluish-green beryls in pegmatite veins near Melkote, Mysore.

The principal source of the Indian stones at present was discovered in 1915 near Daso, in the Shigar valley of Kashmir. Here biotite gneiss is traversed by pegmatite veins containing quartz, orthoclase, albite, tourmaline, garnet and beryl. The best crystals of the gem come from drusy cavities in the central felspathic portions of the veins, where they form transparent crystals from  $\frac{1}{2}$  inch to  $1\frac{1}{2}$  inches wide and 2 to 3 inches long. They tend to be pale and delicate in colour with a noticeable limpidity, especially apparent in artificial light. The colour of the uncut stones is a vivid greenish blue. The last recorded production was 69,471 carats of crystals in 1921.

### CHRYSOBERYL

Sulphur-yellow, platy crystals of chrysoberyl occur with deep blue apatite in the felspar-corundum rocks of the Kangayam neighbourhood, Coimbatore district, Madras. Small crystals of a yellowish tint have been found, again in association with blue apatite, in the vein granite of Ramidi, Cuttack district, Orissa. Transparent yellow stones of good quality are said to have been obtained with aquamarines in mica-bearing pegmatites at Govindsagar, Kishengarh State, Rajputana.

The only locality, however, where the mineral is regularly cut is Mogok, Burma, where it sometimes occurs in the local gem-bearing gravels. Bright, lustrous, sea-green, simple crystals are known, as well as beautifully transparent, wine-yellow and practically flawless trillings.

*Phenacite.* In chemical composition chrysoberyl is an aluminate of beryllium, and it is appropriate to mention here another rare gem stone which also contains beryllium and which is obtained at Mogok. Phenacite, an orthosilicate of beryllium, yields transparent, colourless, brilliantly lustrous stones which resemble the diamond somewhat, though they do not possess its 'fire'.

*Euclase.* The mineral euclase, which is mentioned as occurring with the Kashmir sapphires, is a silicate of aluminium and beryllium which has been cut as a gem stone in some countries. It is usually



sea-green or pale blue in colour, and is said to resemble aquamarine very closely. It is not known whether the Kashmir specimens are actually utilized by the local lapidaries or not.

## DIAMOND

The Indian diamond industry is believed to date only from the sixth or seventh century B.C., but it is the oldest one of its kind and possessed a monopoly of the gems until the discovery of the Brazilian fields in 1727. It is not surprising then that most of the great historical diamonds are of Indian origin, yet today the production of the gem is insignificant. Tavernier's account of his visit to the Indian diamond fields is contained in his *Travels*, published in 1665, and many of the localities mentioned have been identified through the labours of Valentine Ball. There are three extensive and widely separated tracts in which diamonds occur. The most southern, erroneously called 'Golconda', lies in the Anantapur, Cuddapah, Bellary, Kurnool, Kistna, Guntur and Godavari districts of Madras. The second occupies a region between the Mahanadi and Godavari valleys. The third, an area of about 600 square miles, in which the industry still languishes around Panna, is situated in Bundelkhand. In the southern tract the workings were mainly in alluvial gravel deposits of sub-recent age, but in Kurnool the stones were found in situ at Banganapalle and elsewhere. Here, underlying 20 or 30 feet of quartzite, easily pierced by shallow shafts, are beds of coarse conglomerate and breccia with seams of shaley and clayey stuff, six to eight inches thick, full of small pebbles and fragments of shale, quartzite, chert and grains of quartz. In these seams the stones occurred, mainly as small, pepper-corn sized modifications of the octahedron, pale blue, green or yellow in colour and unworn. The Banganapalle rocks form the lowest stage of the Kurnool series of Southern India. The whole series is unfossiliferous and is included in the Purana group of pre-Cambrian age. It is possibly equivalent to the Lower Vindhyan of Central India.

The Great Mogul diamond, the largest Indian stone known, is believed to have been found about 1650 in alluvial workings on the banks of the Kistna, at Kollur, in the Guntur district. It weighed 787½ carats in the rough and was cut to 240 carats. Ball believed that it was later cut to form the Koh-i-Noor (106 carats).

Valuable stones often of large size are said to be found every year

near Wajrakarur in the Anantapur district, Madras, where there is an intrusion of altered plagioclase-augite rock, though whether this has anything to do with the origin of the gems is doubtful.

In the second tract, stones have been found in the alluvium of the Mahanadi river in the Sambalpur and Chanda districts of Bihar and Orissa and the Central Provinces, respectively. The source of the stones is unknown, but Ball thought they might have been derived from extensions of the Kurnool or Lower Vindhyan rocks into the areas in question.

The third tract, comprising the diamond fields of Central India, lies along the northern scarp of the Upper Vindhyan. These are subdivided into three divisions, and diamond-bearing conglomerates exist both at the top and bottom of the middle one, the associated pebbles being derived from the Bundelkhand granite and the lower Vindhyan. The lower conglomerate contains vein quartz, jasper and green quartzite, while fragments of galena are frequent in it. It is a compact rock, not absolutely continuous and seldom exceeding two feet in thickness. The higher conglomerate probably only contains vein quartz. Both bands are reached by wide shafts up to 50 feet deep, and are also mined on the outcrops, while the gems also occur in eluvial and alluvial deposits of limited extent derived from them. The conglomerate is broken up and washed to recover the stones. The whole subject was exhaustively investigated by the late E. Vredenburg, whose work should be consulted for further details. He believed that the diamonds of these conglomerates as well as those of the Kurnool formations of Southern India are derived from basic dykes of Bijawar age. Panna diamonds belong exclusively to a few modifications of the hexakis-octahedron, an octahedron having a low six-sided pyramid raised on each of its faces. The stones are usually remarkably perfect, of a brilliant white to a beautiful blue-white colour; grey, yellow, green and brown stones also exist. Unfortunately they are often spotted with black inclusions. The average weight of 240 stones examined by Vredenburg was 0.59 carat, only 6 per cent being over 2 carats. For the five years ending 1928 the average annual production in Central India was only 224 carats, valued at Rs. 36,237. The average output for the five years ending 1933 was 1,436 carats, valued at Rs. 74,040. In 1934, 2,480 carats, valued at Rs. 1,22,501, were won.

## FIBROLITE

Fibrolite, a massive variety of sillimanite, a silicate of aluminium, is occasionally cut as a gem stone at Mogok, Burma. It forms transparent, pale sapphire-blue stones, somewhat resembling iolite, the water-sapphire. Its hardness is 7.5 so that it readily scratches a quartz crystal. Some varieties are translucent with a high degree of chatoyancy, and have been termed 'fibrolite cat's eye'. They resemble cymophane, a variety of chrysoberyl.

## GARNET

Garnet as a gem stone appears to have been more appreciated in ancient times than it is today. 'The carbuncle of the ancients is garnet cut, as it is called, *en cabochon*. The art is still practised in India, and the stones, when of good quality and well cut, are very beautiful and would meet with more esteem were it not that they happen to be cheap, which has put them within the reach of so large a circle that they are made but little use of' (V. Ball). Fine necklaces of gold set with garnet and amethyst have been found in graves of the second civilization in Egypt, 7,800 to 9,000 years old. They were probably sought for in India long before the Christian era, for the country is believed to have furnished stones for the Greek and Roman lapidaries. Jewels of garnet, topaz, carnelian and rock crystal were found in the stupa at Piprahva where Gautama was buried about 483 B.C.

Precious garnet is mined in certain of the Rajputana States, Jaipur, Udaipur and Kishengarh and in Ajmer-Merwara. The stones come from the soil covering hollows on the surface of the Aravalli schists, especially where these are traversed by granitic intrusions; from shallow workings on the outcrops; and from the beds of rivers which drain these rocks. Mining appears to be carried on intermittently, and the returns may be blank for several years and then show the production of a few tons, which it doubtless takes the market a very considerable time to absorb. Thus 7.3 tons were reported from Jaipur in 1930 after a decade with no output at all. The finest stones come from the Sarwar district of Kishengarh. They are cut in Jaipur and Delhi and a portion of the production still finds its way abroad, as the stones are obtainable in London. Practically all the garnets faceted in India belong to the variety known as

almandite and are usually of a lustrous deep red colour, often tinged with purple. Garnet of gem quality is found at many other localities, amongst which may be mentioned Gharibpet, Warangal district, Hyderabad, which was referred to by Vosey in 1833 and from which large quantities of stones were at one time sent to Madras to be made up into ornaments. A neighbouring area, Khammamett, furnished many parcels for export to Europe, some ten years ago.

Hessonite, or cinnamon stone, a yellow or yellowish-red garnet which bears a superficial resemblance to the true hyacinth or jacinth (the yellow zircon), occurs in the Nilgiri hills near Ootacamund, Madras, and in some of the crystalline limestones of the Central Provinces. Spessartite, a garnet containing manganese, is common in certain rocks of the Central Provinces. It varies in colour from a beautiful bright orange to a reddish-brown, but is seldom free enough from flaws to be cut as a gem. Uvarovite, the emerald-green chrome garnet, occurs near the Hanle monastery in Rupshu, Kashmir. Dark brownish-red varieties of almandine are obtainable at Mogok, Burma.

### IOLITE

Amongst the relics excavated at Buddh Gaya about 1880 and believed then to be some 2,000 years old, were several pieces of iolite, the gem known to jewellers as the water-sapphire, and distinguished by its remarkable dichroism. It has since been found in violet patches and spots in a granite dyke near Thiruvella, Travancore. It occurs also in mica schists near Kiranur and Udaiyapatti, on the Kadavur estate of Trichinopoly district, Madras, where old pits in the vicinity seem to indicate organized search for the stone at one time. The best locality, however, is Mogok, Burma, where it is found in the gem-bearing gravels. When cut the stones are of an attractive, pale, smoky, violet tint. Iolite is also known as cordierite, and a beautiful violet rock of metamorphic origin, collected by the writer near Mogok, was determined by J. A. Dunn to consist of garnet and cordierite with hypersthene, felspar and quartz. It is doubtless from metamorphic rocks such as these that the mineral has found its way into the gem gravels.

### KYANITE

According to Max Bauer, the well-known authority on precious stones, the best crystals of gem kyanite are said to come from unknown

localities in India—a country in which it is more extensively used than in Europe. ‘There is no doubt,’ writes Bauer, ‘that kyanite is obtainable at many places in India, but it has been suggested that the stones worn in that country have all come from Europe.’ The suggestion is incorrect, for kyanite is a common constituent of the Archæan rocks of India, and has been reported from the Himalayas, the Punjab, Hyderabad, Bihar and Orissa and Madras. It is particularly abundant in the schists and granites about Kanaur and Bhabeh, and throughout Bashahr State in the western Himalayas, where it has been repeatedly mistaken by natives and inexperienced Europeans for sapphire. When quite transparent, which is unfortunately not often its condition, it makes when properly cut a very pretty gem, varying from a deep cornflower shade to a pale sky-blue. It is used by lapidaries at Patiala, their material being derived from bluish, thin-bladed, as well as short and thick crystals, found usually in association with calcite in the hills just west of Narnaul, the chief town of the district of the same name in the Patiala State, Punjab. An interesting peculiarity of kyanite crystals is their varying hardness, so that they can be scratched by a knife in some directions but not in others. Kyanite has the same chemical composition as fibrolite, better known as sillimanite, and both minerals in their coarser and more massive forms are useful refractories.

## PERIDOT

The peridot is a form of chrysolite or olivine, a mineral common enough in volcanic rocks in India, though very rarely in a fresh enough state, or sufficiently clear, to be cut for use as a gem stone. According to Max Bauer, ‘the source of the chrysolite which is used in the trade for cutting as gems is somewhat obscure, and both Pegu and the country of the Burmese are mentioned as localities for chrysolite, but the occurrence of the stone in gem-quality here or in India, is by no means well authenticated’. The greater portion of the world’s supply of peridot has for centuries come from the Island of Zebirget (St. John) in the Red Sea, and the doubt regarding the Indian localities may now be dispelled. Peridot occurs in some quantity in gem-gravels of certain parts of the Bernardmyo valley, some ten miles north-north-west of Mogok, Burma. As it is a comparatively soft stone, and as the pieces when found are only slightly roughened and still show their crystal outlines, it is believed that they have not

travelled far and are in fact derived from certain ultrabasic rocks which are plentiful locally. In colour the stones vary from shades of yellowish-green to olive-green, and large gems for pendants and necklaces are frequently cut from them, particularly in the tabular 'step' form. When such stones are viewed through the table facet, they display an apparent doubling of the opposite edges owing to the high double refraction of the mineral.

## RUBY

'It is the rubies of the Burmese Empire which are its greatest boast, as both in brilliance and clearness they are the best in the world,' wrote Father Sangermano, who lived in Ava between 1783 and 1806. The earliest reference to the mines is in a royal edict of 1597, but at that time ruby mining was an old-established industry. They are alluded to in the writings of various early European adventurers in the East—Stefano (fifteenth century), di Varthema (1496), Barbarosa (1501–16), Frederic (1569) and Fitch (1586). The earliest record of a visit to the mines was not given until 1833 by Père Guiseppe d'Amato. These mines have undoubtedly yielded the greater part of the rubies used in the world's jewellery, including the finest specimen stones known, for although rubies do come on the market from Siam, Ceylon and elsewhere, the clear, limpid, deep crimson-red of the Mogok ruby is incomparable. The shade which is most admired is a transparent carmine-red with a suggestion of a bluish tinge which gives the famous 'pigeon's blood' stone. (The term is derived from the Hindustani, the Indian lapidaries comparing a faultless ruby with the blood-red colour of a living pigeon's eye.) Siamese rubies are usually of a dark claret colour, while the Ceylonese stones tend towards magenta.

The Mogok Stone Tract is an area of over 600 square miles of mountainous country in the Katha district of Upper Burma, and the productive region is at the eastern end of the tract. It is made up of gneisses and associated rocks of Archæan age, amongst which are the crystalline limestones from which the rubies and spinels have been shed into the detrital and eluvial deposits, and from which they are now won. The native workings which still flourish are either underground drives along the lines of fissures in the limestone, or open excavations made into hill-sides, or shafts sunk into the alluvium of the valley floor to reach the gem-bearing gravel below. In 1889 a lease of

the Mogok Tract was granted to the Burma Ruby Mines Ltd., which carried on systematic mining operations in the alluvial deposits with varying fortunes until June, 1931. The gravel was dug or washed out of large quarries by hydraulic methods, classified into different sizes, and treated by pulsators and tables to produce a clean concentrate from which the gems were picked by hand. In the most prosperous periods gems to the value of approximately £1,000,000 were produced per decade, taking into account both native and European workings. No complete statistics are available of the production of the existing native industry, as the Government is only concerned with the collection of licence fees from the miners, who are under no obligation to report the quantity or value of their finds. The greater proportion of the rubies are small, but occasionally exceptionally large stones have been found. It is a commonplace remark that the ruby is a more valuable stone than the diamond, but this only applies to perfect rubies of large size. The best quality ruby begins to rival a diamond of the same class when it is about 2 carats in weight, but beyond that the ruby greatly exceeds the diamond in value. Diamonds of large sizes are comparatively common, and 10-carat stones can be had in abundance, but a perfect ruby of 10 carats is a most exceptional rarity. Large rubies of superb quality are perhaps the most valuable minerals known to mankind. Two stones brought to Europe from Burma in 1875, weighed 37 and 47 carats; when re-cut the stones weighed 32.3 and 38.6 carats respectively. It is recorded that the smaller stone brought £10,000 and the larger one £20,000. A stone weighing 77 carats in the rough, found by the Company in 1889, was valued at Rs. 4,00,000 (£26,666). Another weighing 9 carats sold uncut for Rs. 27,000 and when cut to 6 carats, brought £7,500. Yet another, weighing 36 carats, was sold by King Mindon Min for £30,000. The great 'Peace Ruby' of 1919, a superfine stone of magnificent colour, weighed 42 carats. Except for a fracture estimated to take away a slice of about 8 carats, it was perfect and sold in the rough, on the spot, at Mogok for Rs. 3,00,000 (£22,500). In October, 1932, the discovery of a fine stone weighing about 30 carats and valued at £7,000, was announced from a native mine in Mogok, while on 3 February 1933, *The Times* stated that a rough ruby, weighing nearly 20 carats, recently found in Burma, had been cut in Hatton Gardens to a weight of  $7\frac{1}{2}$  carats and was valued at nearly £10,000.

Many adverse causes have contributed to the present depressed condition of ruby mining in Burma, but the writer after lengthy investigations in the Stone Tract, came to the conclusion that exhaustion of the gem-bearing deposits as a whole was not one of them. The market for the stones is a world-wide one, but it is extremely sensitive to economic conditions, enjoying prosperity in times of general industrial activity and slumping when the purchasing power of the nations decreases. The trade has suffered, too, from the competition of synthetic stones, but these are distinguished easily enough by the initiated, and the discriminating buyer prefers the natural article.

Rubies also occur near Sagyin in the Mandalay district and at Naniazeik in the Myitkyina district of Upper Burma, but no mining has been done at either locality for many years.

### SAPPHIRE

Sapphires accompany rubies in the gem gravels of Mogok, Burma, but the stones are not derived from an identical mother rock. The matrix of the ruby is the local crystalline limestone, the sapphire, sometimes found intergrown with felspar, may come from the pegmatites and nepheline-corundum syenites. The rubies when they exhibit their crystalline forms are practically always combinations of hexagonal prisms and basal planes, sometimes with subsidiary rhombohedral faces and generally of a tabular habit. Sapphire crystals, on the other hand, always show steep pyramidal planes, whereas rubies having them are exceedingly rare. Mogok supplies exceptionally fine star-sapphires, which when cut in the proper direction and *en cabochon*, exhibit a six-rayed, opalescent star. The blue shade of the sapphire varies a great deal, from quite a pale colour to a dark indigo hue, but the most prized varieties are the cornflower blues which have at the same time a soft velvety sheen. The Burmese gems as a group tend towards the darker tints. The rubies occur in much greater numbers than the blue stones, though the latter are often of considerably larger sizes. For example, stones of 630 and 293 carats were found at Kathe, not far from Mogok, in 1930, while a specimen weighing 514 carats came to light in a native working at Mogok, in December, 1932; but probably the record stone was one found at Gwebin, on 12 August of the same year, which weighed nearly 1,000 carats. Sapphires are very much cheaper than rubies, and as a general rule a perfect ruby of medium size, is rated at ten times the



value of a similar sapphire. Yellow, purple and green sapphires, which are known to jewellers as the 'oriental topaz', 'oriental amethyst' and 'oriental emerald' respectively, have all been recorded from Mogok, but they are rare. The colourless transparent stone called the 'white sapphire' is commoner.

Kashmir sapphires first came on the market in 1882, and in 1888 La Touche examined the occurrence. It lies at an altitude of about 14,000 feet, on the southern slopes of the Zangskar range, below the Umlasi pass, and is inaccessible for the greater part of the year. The local rocks are garnetiferous biotite gneisses, lenticular masses of green amphibolite and crystalline limestone, which are intruded by a pegmatite vein containing sapphires, black tourmaline, green euclase, kyanite and garnet as accessory minerals. The stones come from the eluvial detritus of the vein, shed into the valley below, and after yielding much revenue to the State, the mines were abandoned. In 1906 work was restarted by the Kashmir Mineral Co., ceasing again in 1908, although some valuable gems were obtained. In 1927 the deposit was worked experimentally with good results. The area is not exhausted, and in 1930 was still elaborately policed to prevent theft, by 'adventurous gangs of hardy smugglers who have recently sprung up and come to regard these regions as their own particular hunting-grounds' (Middlemiss). A few pale rubies and red and green tourmalines have also been obtained from it. Systematic production of the stones commenced again in 1933. Specialists who have seen the gems from this locality stored in the State Treasury at Jammu, declare that the choicest specimens are probably unequalled for size and colour.

## SPINEL

The concentrate from the gem-bearing gravels of Mogok, whether recovered in the pan of the native miner or the washing machines of the European company, consists largely of spinels of many kinds. As long ago as 1850, Dr Mason pointed out that spinel was one of the constituents, and in the samples of gem sands he examined, the mineral made up more than three-fourths of the whole mass. 'A single handful will contain specimens of every shade—black, blue, violet, orange, amber-yellow, wine-yellow, brown and white. Many retain their original crystalline forms; some have the fundamental form of the species, a perfect octahedron; but many others have some of

the secondary forms, among which it is not uncommon to see twins with three re-entering angles, formed by two segments of the tetrahedron truncated on the angles and joined together by their bases.' The same authority distinguished the blood-red form as the proper spinel ruby, the rose-red as the balas ruby, an orange-red kind as rubicelle, and a violet-coloured variety as the almandine ruby. The gorgeous red, scarlet, rose and pink spinels of Mogok certainly rival the true ruby in beauty, although large and perfect stones are only worth a fraction of the price of that very much rarer gem. After cutting, the deep red spinel is easily and frequently mistaken for the ruby, and the dichroscope furnishes a means for the safest test. Fine blue spinels are also cut at Mogok, but they are not common.

### TOPAZ

Although topaz was used as a jewel in India in the fifth century B.C., it was not until 1900 that it was first recorded in Indian geological literature, when colourless crystals were detected in a parcel of gem stones from the Katha district, sent by the Government of Burma to the Geological Survey office for determination. It is also found in association with fluorite in a cassiterite-bearing vein at Hermyingale, and in a granular form with alluvial tin stone, at Taungthonlon, both in the Tavoy district, Burma. The so-called 'oriental topaz', referred to by early writers on Indian gems is, of course, the yellow sapphire. Yellow quartz or citrine has also been termed topaz in the past.

Topaz has been found recently to occur freely with certain rocks of the 'kyanite belt' in Singhbhum, though whether they will furnish material of gem quality remains to be seen. In the vicinity of Kanyaluka, in the Dhalbhum subdivision, there are veins and patches of pale blue topaz in boulder outcrops of quartz-kyanite rock. It is also common in quartz-kyanite rock south-east of Bakra, while at Ghagidih, also in the Dhalbhum subdivision, a topaz rock, apparently continuous with kyanite rock, has yielded large crystals. Topaz granulites passing into topaz-muscovite schists, with small but well developed crystals, and coarse-topaz pegmatite occur at Lapsa Buru, Kharsawan State, Singhbhum.

Pellucid, perfectly colourless and slightly water-worn crystals, sometimes exhibiting the rare double terminations, are found in the gem gravels of the ruby mines, but the finest specimens yet produced were obtained when the great pegmatite dyke at Sakangyi, in the

Mogok Stone Tract, was mined for rock crystal about 1923. Exceptionally large crystals up to 9 inches in length and 5 inches broad, of a pale straw-yellow colour, were obtained, as well as very numerous much smaller, water-clear and more complex forms. Colourless topaz is hardly regarded as a precious stone by the lapidaries in Mogok and is worth little more than the cost of cutting.

*Danburite.* Danburite, a calcium silicate which contains boron, is a mineral which has the same crystalline form and habit as topaz, and its pale yellow and colourless, water-worn crystals, which occur rarely at Mogok, are very liable to be mistaken for the latter. It does not possess the highly perfect cleavage of topaz and is therefore more suitable for the gem stones into which it is sometimes cut.

## TOURMALINE

Precious pink tourmaline, or rubellite, was mined sporadically under Chinese supervision for over two centuries, until about 1910, near Maingnin, Mong Mit State, which adjoins the Mogok Stone Tract of Burma on the north. The matrix of the gems was a thick, decomposed granite-pegmatite and the methods followed were those of the native ruby miner.

Rubellite also occurs in the older alluvium of the Nam Pai river, near Naungdaw and Naungheng, Mainglon Sub-State, to the south of Mogok, where it has been mined casually from time to time by the Chinese. The surrounding hills are built up of gneisses, penetrated with thick veins of pegmatite from which the stones are derived.

The mineral is also believed to occur at some unknown locality in Kengtung, the most eastern of the Southern Shan States.

Specimens of rubellite still exist in the stocks of some of the native gem dealers in Mogok, but they are scarce and rather costly. Lovely multicoloured, sheaf-like growths of columnar tourmaline crystals, each terminated by a squat pyramid, and growing close together in divergent form from a common base, and of varying shades of red, purple and green, have been seen by the writer in Mogok, but their locality is not known. They recall the magnificent specimen given to Major Symes by King Bodopra in 1795, which is now in the British Museum.

Namon, in the Salween valley of Karenni, used to supply transparent and brilliant, dark emerald-green crystals, varying in size from a pea to a bean, which were for a time successfully sold in Rangoon

as emeralds. According to Middlemiss (1900) they are shed from crystalline limestone into a sandy surface clay, which is removed by pitting, and washed to recover the gems.

Blue and brown kinds occur at Lapsa Buru, Kharsawan State, Singhbhum, Bihar, and both blue and green tourmalines have also been found in the mica-bearing pegmatites of the Hazaribagh district, Bihar.

Light green tourmaline crystals occur in a granite vein about one mile from the Kashmir sapphire mines, and are fairly numerous in some parts of the rock, thickly encrusting or penetrating large quartz crystals. They are transparent, very thin in proportion to their length, seldom reaching more than two inches, with a breadth of about one-eighth of an inch. Rubellite with the tint of the pomegranate, also comes from the same locality.

### JACINTH, HYACINTH, OR ZIRCON

The hardness, high refractive index and great dispersive power of zircon render it a valuable gem. 'In refraction and dispersion it comes next to the diamond among precious stones; it further possesses a very great range of colour' (Miers). The finest specimens come from the alluvial gem gravels of Ceylon, where the red variety is termed the hyacinth or jacinth, and the name 'jargoon' is given to other transparent kinds, especially to the yellow stones. From this latter term, the word 'zircon' is derived.

Zircon is obtained from the gem-bearing gravels of Mogok and other valleys of this famous Stone Tract in Burma, but its original home, according to Professor Judd, is the crystalline limestones. The demand for the gems has increased rapidly in Burma in the last few years, and it is suspected that it is to some extent satisfied by the importation of rough stones from Colombo which are cut in Mogok to augment the local supplies. Mogok zircons usually crystallize in four-sided prismatic forms, longer than broad, and terminated at both ends with a squat pyramid. The colours found vary from golden yellow and flame-coloured, to many brownish shades of yellow and orange; greenish, greyish, sky-blue and steely-blue stones are also obtainable. It is said in Mogok that the blue tints are obtained by heating the brown stones to a high temperature in a ball of lime, and that the colour is not quite permanent, especially if the stone is much exposed to strong sunlight. It is claimed, however, that blue stones

## CHAPTER XIV

### SEMI-PRECIOUS STONES : AGATE AND OTHER FORMS OF CHALCEDONIC QUARTZ, AMETHYST AND OTHER FORMS OF CRYSTALLINE QUARTZ, THE ORNAMENTAL FELSPARS, AMBER, APATITE, BOWENITE, EPI- DOTE, JADEITE, LAPIS LAZULI AND RHODONITE

#### CHALCEDONIC QUARTZ

AGATE and carnelian, with their numerous relatives, are forms of chalcedony, a translucent, cryptocrystalline variety of silica. Beads of beautiful workmanship, dating from a period not later than 2,700 B.C., have been found at Mohenjo-Daro in Sind, fashioned from agate, agate-jasper, jasper, onyx, bloodstone and chalcedony, thus antedating by more than 2,000 years the reference of Ctesias, the Greek physician at the Persian court of Artaxerxes, to the Indian sources of such stones. India's onyx and carnelian cups were famed amongst the Greeks and Romans, and her semi-precious chalcedony, exported since the earliest times, has been spread over the world to an extent realized by few.

The chief sources of the stones are the amygdaloidal lava flows of the Deccan Trap, and in certain places there are extensive Tertiary and sub-recent gravel and conglomerate beds made up almost entirely of agate and chalcedony. Collected from such areas or from the rivers draining them, the stones reach the lapidaries at Jubbulpore, Banda and elsewhere.

The most important centre however is Cambay in Gujerat, and although other regions contribute their own special kinds to its craftsmen, the bulk of its rough stones come from Ratanpur and other places in the State of Rajpipla, some 70 miles to the south-east. The workings have been in existence from an unknown antiquity, probably long before they were referred to by the early European

adventurers, Ludovic di Varthema and Duarte Barbarosa in the early years of the sixteenth century. Blanford (1867) stated that the stones occur in a thin ferruginous bed not exceeding a foot in thickness, hut Bose (1908) described a Pliocene conglomerate, 15 feet thick, underlain by a layer of pebbles 3 feet thick, composed exclusively of chalcedonic pebbles, especially carnelian. After sorting at the pits, the stones are taken to Limodra, sun-baked for four months, and then fired to improve and fix the colours. From Limodra they reach the ateliers of Cambay. The methods followed by both miner and lapidary are those of centuries ago. The output from the mines, which are farmed out by the Rajpipla State, varied from 100 to 500 tons per annum. They were closed down in 1917, but yielded 148 cwt. again in 1929.

Of the special varieties of semi-precious chalcedony, many localities in Kathiawar yield moss agate, while veined agates come from Ranpur in Ahmadabad district. Onyx, the parallel-banded agate, is common in Rajpipla, and both it and the red-and-white sardonix are obtainable in Jubbulpore. A gray, banded onyx from Popa, the extinct volcano of Central Burma, commands prices far beyond its intrinsic value, when cut transversely so that the truncated bands form the outline of a pagoda in miniature. Sard, the brown carnelian, occurs at Ratanpur and elsewhere. The bright and brownish-red to dull leek-and apple-green stones, known as plasma and chrysoprase respectively, have been found in the Deccan Trap, particularly in Hyderabad. They sometimes occur with bloodstone or heliotrope, a green chalcedony spotted with red, and banded or single-coloured jaspers of many tints, popular stones for seals and signet rings.

The term 'jasper' as generally used by Indian geologists, refers to a rock rather than a mineral, and banded jaspers are common in the Dharwar and Bijawar formations throughout the peninsula. Pebbles derived from them are of frequent occurrence in river beds. Only one reference to a great number scattered through Indian geological literature is possible. Near Timappaghar, in the Sandur State of Madras, there are great cliffs, 300 to 400 feet in height, formed of banded jasper-hæmatite of vivid red and purplish-grey or greyish-brown tints in stripes, often exquisitely vandyked. The jointing is rectangular, and blocks from a foot cube to several cubic yards in bulk could easily be quarried. Bruce Foote described it as a most richly

coloured rock which even in the rough formed a material of great beauty.

### CRYSTALLINE QUARTZ

The semi-precious forms of crystalline quartz found in India include rock crystal and rose quartz, cairngorm and smoky quartz, citrine or yellow quartz, the chatoyant variety termed cat's eye, and the amethyst. Aventurine is best included here, though it is really a quartzite.

Ancient as the agate industry is, the use of rock crystal as an ornament reaches still farther back into India's dim past, for beads of this mineral have been found in tombs of the Copper age. From the time of the Maurya dynasty (322-185 B.C.) onwards, rock crystal urns and caskets, vases and pitchers have formed part of the royal treasures of Indian emperors.

Rock crystal is cut for cheap jewellery both in Madras and in Kashmir. The small, brilliant and limpid, doubly terminated crystals from the gypsum of the Salt Marl, near Kalabagh on the Indus, are also collected and sold. In 1922-23, a pegmatite dyke at Sakangyi, in the Katha district of Burma, was mined for its enormous rock crystals, some of which were over 6 feet in length. The crystals were bought for large sums by Chinese merchants and exported to their country, though remnants are still cut into spectacle lenses in Mogok. A crystal sphere, 30 inches in diameter, now in the National Museum of the United States at Washington, was carved from one of them.

Disused rock crystal quarries exist at Nawai in Jaipur State and at Hathuna in Tonk State, Rajputana.

Good rose quartz of pink to deep rose shades comes from the nanganese mines of the Chhindwara district, Central Provinces and from Kodur, Vizagapatam, Madras.

Yellow quartz or citrine, cairngorms and smoky quartz occur in the beds of streams draining the plateau of Cuddalore Grits, of Tertiary age, near Vellum in the Tanjore district of Madras and are collected for the use of local lapidaries.

Fine quartz 'cat's eyes' come from the Malabar coast and from Rajpipla. They exhibit the opalescence or chatoyancy of the true cat's eye, a variety of chrysoberyl.

Amethyst is not an uncommon mineral in cavities of the Deccan Trap and of the basalt near Burhait, Santal Parganas, Bihar and

Orissa, but the colouring of the stones is often uneven, the crystals being patchy or zoned. The stone is also found at several places in the Sutlej valley in Bashahr, Punjab and occurs in the Mogok Stone Tract, Burma.

*Avanturine.* Max Bauer in his work on *Precious Stones* writes: 'Fine specimens of avanturine are occasionally met with in India, but nothing definite is known as to their mode of occurrence or the exact locality. A very pretty, green, glistening variety from the Bellary district of Madras deserves mention; the scales of mica enclosed in it are of the green chromiferous variety known as fuchsite, and the mineral itself occurs in blocks from which slabs of considerable size can be cut.' This green quartzite occurs in a low ridge a few score yards south-east of Metra, on the road between Daroji and Kampli, Bellary district, Madras. In Mysore, a uniformly rich bluish-green quartzite is found near Belvadi, Hassan district, while a banded green variety occurs near Sindagere, about three miles north-west of Belvadi. Green quartzites of Dharwar age are also common in the Bensibetta ridge, the Karayanbetta hill, and other localities in the Coimbatore district, Madras.

It has been stated that green avanturines of these types are highly esteemed in China and are sometimes substituted for jade and jadeite, but specimens of South Indian fuchsite quartzite, given to the jade cutters of Tengyueh, Yunnan, excited little interest on account of the brittleness of the stone.

Dr A. M. Heron has described smooth, pale and dark green ovoid beads, sold by jewellers in Rajputana and Kashmir as 'beryl' and 'jade' respectively, which on examination proved to be fuchsite quartzite. A similar material, after treatment with a suitable dye, passes as 'pink topaz'.

A vase fashioned from a green mica rock, apparently pure fuchsite, was found recently at Mohenjo-Daro. Its age is stated to be not later than 2750 B.C.

## ORNAMENTAL FELSPARS

Large crystals of the beautiful green opaque or very slightly translucent potash felspar, known as amazon stone, occur with pink and blue tourmalines in the druses of a cavernous pegmatite, two miles south of Domchanch, Hazaribagh district, Bihar and Orissa. The stone also occurs in Kashmir and elsewhere.



Moonstone, a variety of orthoclase felspar with a pearly, opalescent, internal reflection is cut *en cabochon* and sold in Mogok, Burma.

Blue iridescent varieties of the plagioclase felspar known as labradorite are also occasionally cut for sale in the same place. They are derived from the local syenites.

Murchisonite is a variety of orthoclase felspar, which sometimes forms thick beds and seams of massive and granular kinds in the garnetiferous feldspathic rock edging the alluvium and stretching from the Kistna district into Vizagapatam, Madras. 'The felspar is generally a reddish or a pale salmon colour, weathering lighter, but it is frequently of a decided red, even rosy-red, and then, on well-worn and smoothed surfaces it has somewhat the look of rhodonite, while it has nearly always a fine pearly, silvery or bright bronze sheen' (King).

Murchisonite and sunstone, or aventurine oligoclase, which possesses a spangled appearance and has internal reddish fiery reflections, perhaps produced from inclusions within the mineral, were both recorded from Mogok by Professor Judd.

## AMBER

Dr Berthold Laufer, a learned sinologue, has recently proved from Chinese sources that the exploitation of the amber mines of northern Burma must date back to at least the first century of our era, if indeed they were not worked in far anterior times. The earliest European account of the mineral was given by the Jesuit Father, Alvarez Semedo (1643). The fact that both he and the early Chinese writers from the third century onwards refer to Yung-Chang-Fu, a city in western Yunnan, as the source of the amber, does not mean that it was actually mined there. The city was merely the transit mart between Burma and China. In much the same way Golconda was not the actual source of India's famous diamonds. In nearly all Chinese literature dealing with Burma the amber production of the country finds a place.

The mines lie around Maingkwan in the unadministered Hukawn valley. They have been visited by Hannay (1836), Griffith (1837), Noetling (1892), Stuart (1920) and Chhibber (1930). The largest active centre at present is at Khanjamaw, and here, as elsewhere, the mineral occurs in irregular lumps in a blue clay or as small nodules



DIGGING FOR AMBER IN THE HUKAWN VALLEY, BURMA

in firmly bedded shales. Both rocks are of Eocene age. Shallow pits up to 45 feet in depth are dug on the outcrops in search of the mineral (see Plate VIII, from a photograph by H. L. Chhibber). The potentialities of the region are unknown, though the existence of new amber-bearing areas at depths below those reached by the local miners is not improbable. Mining methods are primitive in the extreme, and the workmen members of indolent and semi-civilized tribes. Their results are largely a matter of chance, and it is not surprising that the output fluctuates within wide limits. Thirty years ago it ranged between 100 and 200 cwt. per annum, but is now nearer a fifth of these figures. The right to collect a 5 per cent *ad valorem* duty on amber is 'farmed out' with the jadeite royalties, and the production statistics of both minerals are not reliable.

Burmese amber is slightly harder and of higher specific gravity than Baltic amber. It occurs in many shades, varying from pale honey yellow to golden and reddish-brown. It is remarkable for its strong fluorescence. The material finds its way partly to Tengyueh, the jadeite cutting centre of Yunnan, where it is made up into buttons and small ornamental articles, and partly to Mandalay, where beads for rosaries, *nadaungs* (the ear cylinders worn by Burmese women) and trinkets are made. Burmese amber beads are familiar objects in the bazaars of Indian cities, but there are many excellent imitations of artificial origin on the market to attract the unwary purchaser.

## APATITE

Apatite of an attractive blue colour occurs with ruby, sapphire and spinel in the gem-bearing gravels of the Mogok Stone Tract, Burma, where it is cut and sold as faceted stones for rings and necklaces. A remarkable, deep sea-green variety has been found at Devada, Vizagapatam district, Madras, and a lavender-coloured, though much flawed kind at Kodur in the same district. Green apatite from the pegmatites of Ajmer in Rajputana is sometimes cut as a gem, though the stone is really too soft for this purpose. Burmese apatite is more strongly dichroic than usual, the colours it exhibits being yellow and greenish-blue. Apatite is a phosphate of lime in part, and in addition to these varieties, there are others which are utilized for their phosphatic contents (see PHOSPHATES).

## BOWENITE

Small ornamental articles cut from bowenite are obtainable in many Indian bazaars and are traded about the country by pedlars. The mineral itself, known as *sang-i-yeshm*, is a green, massive variety of serpentine, which resembles true jade very closely. Indeed, for some time the stone was actually called nephrite by mineralogists. It is mined in the Safed Koh of Afghanistan and brought down to Bhera where it is cut for sale. Similar material is said to be found in Khotan, whence it is carried along with true jade to Kashmir, where the two are sold together in Srinagar. Cups and small vases are extensively manufactured at Shigar in Baltistan, from a translucent apple-green bowenite sometimes shading into a sulphur-yellow or bottle, grass and dark green. It occurs in the neighbourhood in rocks of doubtful age, at an elevation of over 18,000 feet above sea level, so that mining is limited to two months during the year. Though substantially the same in chemical composition, the Afghan mineral varies in colour from a dark greenish-grey to pale sea-green, mottled with white and apple-green.

Mottled and veined, dark and light green serpentine occur at various other localities in Kashmir.

Hard, compact, transparent, dark and light green bowenite also occurs with calcite, in small quantities, near Bamanvada, Idar State, Bombay. The local rocks belong to the Aravalli system.

## EPIDOTE

A hard, compact, dark yellowish-green to pistachio-green variety of epidote is sometimes found in water-worn pieces good enough in quality to be cut into gem stones at Mogok, Burma, though its perfect cleavage renders it easily liable to flaws. Owing to its peculiar dark green colour it is not a very attractive stone.

A handsome gneissose rock containing large flesh-coloured crystals of orthoclase felspar and yellowish-green epidote, known as unakite, has been found in Singhbhum, Bihar and Orissa.

Red aplites, streaked with pistachio green epidote, occur north of Beawar in Ajmer-Merwara and about Desuri and Bijapur in Jodhpur State, Rajputana. Dark green, massive epidote has been mistaken for jade in Burma.

Two beautiful minerals known as piedmontite and thulite, which

are closely related to epidote, are known to occur in India, but do not appear to have been utilized as gem stones. The former occurs at several localities in the Archæan schists where the rocks of the Gondite series are found (see MANGANESE). It ranges in colour from black and reddish-black to deep crimson. The variety from Kajlidongri, Jhabua State, Central India, has a pansy-purple tint. Streaks and patches of purple thulite occur in certain sillimanite rocks of Pipra, Rewah State, Central India.

### JADEITE

Jade is the name popularly bestowed on certain semi-precious stones, which mineralogists distinguish as nephrite or jade proper, a member of the hornblende or amphibole group, and jadeite which is an alkali pyroxene. On account of its colours, toughness and supposed magical properties, jade, using the term in its inclusive sense, has been cherished by mankind from prehistoric times onwards. The ancient beliefs have descended through the centuries to the modern Chinese, and from times antecedent to the Chou dynasty (1122-255 B.C.) the stone has formed the medium through which the religious, social and artistic cultures of the Chinese peoples have found their highest expression. Of late years an increasing appreciation of the beauties of Burmese jadeite has grown in western lands, where it now forms a wide-spread article of feminine adornment.

Burma possesses a world monopoly of the supply of jadeite. Tradition relates that it was discovered accidentally in the thirteenth century by a Yunnanese muleteer picking up a stone to balance a pack animal's uneven load, but it was probably known long before that period. The modern trade dates from 1784, following the conclusion of protracted hostilities between Burma and China, the stone being then transported by the overland route between the two countries, until 1841. The wars between England and China in the intervening years resulted in temporary set-backs until about 1861, since when the bulk of the production, though by no means all, has followed the sea route from Rangoon to Canton. The kings of Burma collected dues from the dealers, and with the British occupation of Upper Burma in 1886, the right to collect the authorized one-third of the value of stone removed from the mines has been auctioned out annually to the highest bidder.

The occurrences lie in the valley of the Uru river, a tributary of

the Chindwin in the Mogaung subdivision of the Myitkyina district, and accounts of them have been given by Griffith (1847), Noetling (1893), Bleek (1908) and Chhibber (1928-31). The mineral occurs in association with albite, forming dykes intrusive into partially serpentized peridotite, themselves intrusive into crystalline schists. The Tawmaw dyke is under active exploitation, and there are others known as Mienmaw, Pangmaw and Namshamaw. Bleek believed that the jadeite was a result of the dynamo-metamorphism of an albite-nepheline rock, but according to Chhibber it is a desilicified magmatic segregation product. Mining methods followed on the Tawmaw dyke are extremely crude, and the workings are flooded every rainy season.

Large quantities of jadeite are also won in the form of water-borne boulders, from certain Tertiary deposits which fringe the serpentine massif, from the thick, sub-recent Uru Boulder Conglomerate and from the bed of the Uru itself.

Chinese dealers classify the stone into many kinds, the values of which vary greatly. This is not surprising in a mineral which may possess any colour from pure white through all the shades of green to amethystine, mauve, violet and light blue; yellow and orange to various tints of brown, red and black. The most precious is a uniform translucent green, best compared with the emerald, or, as the Chinese say, with the green in a peacock's tail seen in sunlight. The leek-, apple-, and pea-green kinds are costly. A very translucent, light grape-green variety of remarkable clarity ranks with them. The limpid whites, flecked and mottled with apple-green shades, are also highly prized. The cheaper stones include the darker greens, mauves and the various hues of blue, orange and brick-red, yellow, rust-red and white, in order of value. Although objects fashioned from Burmese jadeite, such as necklace beads, plaques, ring-stones and small carvings, are familiar enough in Europe and America, the real market for the stone is in Canton, where much of the modern jade carving is carried on, though there is a centre of secondary importance in Tengyueh, Yunnan, mainly concerned with the manufacture of bangles. Some cutting is also done in Mogaung and in Mandalay.

The official returns of production are not reliable, but such as they are they show that the industry is at present in a depressed state. Conditions of general prosperity in China stimulate jadeite mining in Burma, for it is said to be the desire of every Chinese woman and of

most Chinese men to possess ornaments or trinkets of this emblematic stone. Famine, floods and civil war in that country cause depression at the mines.

For the 15 years ending 1923, the average annual production was about 4,500 cwt. For the next five years, up to and including 1928, the average was 2,100 cwt., and for a similar period ending 1933, 2,382 cwt. The declared values are not given as they are believed by the writer to be misleading.

### LAPIS LAZULI

India acts to some extent as a mart for the celebrated lapis lazuli of Badakshan, but there is one locality where the mineral occurs sparingly which seems to have escaped the notice of previous commentators on Indian gems, though its existence has been known there for some time, and that is Mogok, the centre of the ruby mining tract of Upper Burma. Beads of this magnificent azure to deep indigo-blue stone are obtainable occasionally, both there and in Mandalay and Rangoon. Most of it appears to come from hill-side gem workings on both banks of the Dattaw Chaung, a small side stream at the head of the Mogok valley. It should not be confused with its near relative the brilliant purple and pale to deep lilac sodalite, which occurs in association with certain nepheline-bearing rocks of the Mogok Stone Tract.

Bright blue sodalite is also found in large pieces in elæolite pegmatite near Kishengarh, Rajputana, while a colourless variety from the same place has the extraordinary property of assuming an evanescent pink tint when kept in the dark for two or three weeks. The elæolite pegmatites traverse elæolite syenites associated with Aravalli schists.

### RHODONITE

This silicate of manganese, which belongs to the pyroxene group of minerals, is found at many manganese mines in the Central Provinces, Central India, Bombay and Madras. It occurs in a massive form and is usually translucent, light brownish-red, flesh-red and rose-pink in colour. It has been frequently used as an ornamental stone in other parts of the world and was mined in Russia for this purpose as early as 1828. According to Sir Lewis Fermor, at Manegaon and Risara in the Nagpur district of the Central Provinces, there are

considerable quantities of a beautiful rhodonite rock available, while at Chargaon in the same province there occurs a rose-pink variety set with orange-coloured spessartite garnets.



## APPENDIXES

# APPENDIX I

## A SHORT LIST OF SELECTED PAPERS GIVING FULLER INFORMATION ON INDIAN MINERALS OF COMMERCIAL IMPORTANCE

### CHAPTER I

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|-----------|--|
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## APPENDIX II

### INDIA'S MINERAL PRODUCTION IN 1933 AND 1934

(Outputs in tons unless otherwise stated)

FUELS				
	1933		1934	
	QUANTITY	VALUE £	QUANTITY	VALUE £
Coal ...	19,789,163	4,599,830	22,057,447	4,741,425
Petroleum ...	306,009,022 <sup>1</sup>	4,707,959	322,025,280 <sup>1</sup>	4,514,389

METALS AND ORES				
Antimonial Lead ...	1,485	17,997	1,255 <sup>3</sup>	15,617
Beryl ...	324	546	55	124
Bismuth ...	80 <sup>3</sup>	12	...	...
Chromite ...	15,526	16,785	21,576	23,313
Copper Ore <sup>4</sup> ...	201,722	166,388	328,676	257,133
Copper Matte <sup>5</sup> ...	12,550	225,863	11,000	165,404
Gold ...	336,108 <sup>6</sup>	2,078,201	322,143 <sup>8</sup>	2,200,836
Ilmenite ...	52,980	52,980	75,644	73,138
Iron Ore ...	1,228,625	187,813	1,916,918	223,443
Iron (Pig) ...	1,057,837	...	1,320,210	...
Ferro-Manganese ...	7,725	...	5,536	...
Lead ...	72,045 <sup>7</sup>	869,317	71,815 <sup>7</sup>	803,476
Manganese Ore ...	218,307	123,171 <sup>8</sup>	406,306	388,240 <sup>9</sup>
Nickel Speiss ...	3,350	77,333	3,951 <sup>9</sup>	86,401
Silver ...	6,080,241 <sup>10</sup>	497,213	5,817,524 <sup>10</sup>	562,857
Tin Ore ...	4,504	484,034	5,801	764,688
Wolfram ...	2,603	98,885	3,328	284,956
Zinc Concentrates ...	61,432	231,800	68,838	201,309

<sup>1</sup> Gallons.

<sup>2</sup> Contains 18% antimony.

<sup>3</sup> lb.

<sup>4</sup> From mines in Singhbhum.

<sup>5</sup> From Nam Tu smelter.

<sup>6</sup> oz.

<sup>7</sup> Includes antimonial lead.

<sup>8</sup> f.o.b. values.

<sup>9</sup> Averages 30.6% nickel and 4.4% cobalt.

<sup>10</sup> oz.

## GEMS AND SEMI-PRECIOUS STONES

	1933		1934	
	QUANTITY	VALUE £	QUANTITY	VALUE £
Amber ...	76 <sup>1</sup>	113	414 <sup>1</sup>	12
Aquamarine ...	39,000 <sup>2</sup>	52	69,471 <sup>2</sup>	...
Diamond ...	2,342 <sup>2</sup>	4,789	2,480 <sup>2</sup>	9,211
Jadeite ...	2,111 <sup>3</sup>	9,601	2,197 <sup>3</sup>	10,967
Rubies ...	1,103 <sup>4</sup>	44	21,622 <sup>4</sup>	2,708
Sapphires ...	1,464,158 <sup>5</sup>	6,917	1,072,022 <sup>4</sup>	10,473

## OTHER MINERALS

Apatite ...	37	28	59	67
Asbestos ...	...	...	25	311
Barytes ...	5,651	3,122	3,813	2,651
Bauxite ...	1,075	237	18	7
Clays ...	400,525	21,167	367,305	25,806
Felspar ...	677	442	628	474
Fuller's Earth ...	7,663	6,150	8,526	6,787
Garnet Sand ...	295	222	225	169
Graphite ...	...	...	337	359
Gypsum ...	33,142	4,975	46,757	6,860
Kyanite ...	4,283	5,220	9,411	10,760
Limestone ...	3,143,036	302,996	3,990,335	358,493
Magnesite ...	15,206	7,344	14,975	7,385
Marble ...	4,752	12,158	4,907	12,522
Mica ...	2,832 <sup>6</sup>	307,671	4,641	451,547
Monazite ...	139	1,592	1,009	3,885
Ochre ...	11,630	4,578	7,996 <sup>7</sup>	2,844
Salt ...	1,712,397	859,026	1,963,702	877,720 <sup>7</sup>
Saltpetre ...	9,447 <sup>6</sup>	117,128	8,314 <sup>6</sup>	100,614
Slate ...	11,377	14,314	10,179	12,952
Steatite ...	17,048	13,757	9,375	12,800
Zircon Sand ...	675	3,375	354	939

<sup>1</sup> lb.<sup>2</sup> Carats.<sup>3</sup> Exports in cwt.<sup>4</sup> Carats. Figures incomplete.<sup>5</sup> Carats. Includes some corundum.<sup>6</sup> Exports.<sup>7</sup> Incomplete.

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